COMMISSION REPORT

PUBLIC INTEREST ENERGY RESEARCH 2012 ANNUAL REPORT

CALIFORNIA ENERGY COMMISSION

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CALIFORNIA ENERGY COMMISSION

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ABSTRACT

The California Energy Commission manages public interest energy research for electric and natural gas research programs including the Public Interest Energy Research (PIER) Program. PIER supports energy-related research, development, and demonstration for research not adequately provided by competitive and regulated markets.

This report, prepared under Public Resources Code Section 25620.8, describes PIER electric funding and accomplishments in 2012, including activities and research projects funded from January 1, 2012, through December 31, 2012, ratepayer benefits, and program updates and initiatives.

Keywords: California Energy Commission, PIER, annual report, energy research, RD&D, energy efficiency, advanced generation, renewable energy, demand response, energy storage, buildings, distributed generation, transmission, smart grid, carbon sequestration, carbon capture, transportation, environmental, climate change, smart infrastructure, ratepayer benefits, public interest program, electricity, energy policy, loading order, jobs, clean energy, energy infrastructure, electric vehicles, greenhouse gas, Public Interest Energy Research Program, Renewables Portfolio Standard, building efficiency standards, California Public Utilities Commission

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EXECUTIVE SUMMARY

The California Energy Commission's Public Interest Energy Research (PIER) Program funds research, development, and demonstration (RD&D) projects as stipulated in Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) to "develop, and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs." Research priorities are guided by California's loading order of preferred energy resources, by legislative mandates such as the Renewables Portfolio Standard (Senate Bill 1078, Sher, Chapter 516, Statutes of 2002) and the Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006), by plans such as the Energy Commission's *Integrated Energy Policy Report* (IEPR*),* and by stakeholder input.

Investing in innovation is one of the most important pathways toward achieving California's clean energy future. Effective, policy-guided public interest energy research helps innovators and investors plan and design low-cost solutions that will bring California into its low-carbon, diverse, efficient, and reliable energy future. Public energy research is an investment that yields significant benefits and lays the foundation for enormous savings into the future.

This Annual Report to the California Legislature, as required by Public Resources Code Section 25620.8, reports on the PIER program in 2012, including specific information on award recipients, the amount of the awards, and the types of projects funded, along with an evaluation of the success of projects funded and instituted, and recommendations for program improvements.

To date, the Energy Commission has invested more than $839 million for energy research and development, leveraging its investment to attract more than $1.35 billion in match funding. Over 80 percent of the program's research funds were PIER Electric funds. Funded projects provide thousands of direct and indirect jobs to Californians, bolster California's status as a leader in energy innovation, and advance the state toward meeting its goals by helping remove barriers to a clean energy future.

Highlights of 2012 Research

The portfolio of 2012 research contained in this report demonstrates the wide range of advancements provided by public interest energy research efforts. Chapter 2 provides this information in full, but some of the highlights of research and benefits are summarized here.

Job Creation and Private Investment: The PIER program does not just make investments in California's energy future. It also strives to promote private and federal investment in this future. Its effectiveness in this respect was demonstrated again in 2012. An estimated 5,360 Californians were gaining innovation skills and experience working full or part time in 2012 on PIER-funded projects related to electricity use or generation. Since 2000, small grants for energy research made through PIER's Energy Innovations Small Grant (EISG) Program have led to more than $1.8 billion in follow-on investment, including $1.65 billion of private, non-utility follow-on investment. That is nearly 50 times the $34 million the Energy Commission invested in this small-grants program.

Energy Efficiency and Demand Response: It is often stated that the cheapest energy is unused energy. Energy efficiency and demand response research investigates the most effective strategies and technologies to reduce electricity use and demand in the state.

The benefits provided by research directly addressing energy issues can be enormous when results are incorporated into existing state standards. Between 1999 and 2008, the Energy Commission invested $27.6 million in energy efficiency research projects which directly contributed to changes to California's Building and Appliance Energy Efficiency Regulations. These changes are estimated to result in more than $10 billion in net savings for California ratepayers between 2005 and 2025. This level of benefits demonstrates that public RD&D in this area has been a cost-effective investment.

Demand response refers to the practice of encouraging customers to cut their electricity use when needed using contractual or price incentives. While this is a proven approach to peak load reduction, the process can be highly complex and require advanced technologies. PIER funded the development of technologies that enable automated demand response – AutoDR and OpenADR – which are now industry standards. These technologies are already avoiding 260 megawatts of peak load annually and saved California electricity ratepayers an estimated $16.5 million in 2012.

Current RD&D in energy efficiency shows significant potential to yield future benefits. Energy efficiency RD&D projects in 2012 made advancements in identifying technologies and strategies to reduce building plug loads (the energy use caused by plug-in devices), with research achieving 20 to 40 percent reductions in the energy use of office equipment. Another project demonstrated advanced control technologies that optimize building efficiency without expensive retrofits in 252 Target stores in California, identifying over 18 million kilowatt hours (kWh) of electricity savings and $2.4 million in reduced energy costs in 2012. Data center research continued to identify new strategies for reducing energy use for cooling energy-intensive information technology systems.

Renewables, Advanced Generation, and the Energy-Environment Nexus: Research into renewable energy and other clean, advanced energy sources yielded a wide range of results and benefits in 2012. In addition to funding an integrated suite of solar forecasting projects, the Energy Commission funded the development of a renewable energy portfolio model to facilitate local government energy decision making.

Research into advanced combined heat and power (CHP) technologies tested the use of re-engineered automobile engines in micro-CHP installations. Results exceeded the efficiency improvement targets for these natural gas-powered systems and point the way towards cleaner, lower-emission distributed generation capabilities in California.

Energy-related environmental research in 2012 produced results and data that will help better inform and facilitate increased renewable energy permitting. Because environmental concerns can delay the permitting process, the Energy Commission invests in research that helps avoid impacts and establishes best practices. Data gathered in 2012 about Mohave ground squirrel habitat has already been used to inform the Desert Renewable Energy Conservation Plan.

Research in this area also advanced knowledge about ways to reduce bird interactions with wind turbines and transmission lines. This helps not only with siting concerns but also with reliability since bird electrocutions or collisions with transmission lines are estimated to cause more than 25 percent of all power outages.

Energy Infrastructure: Research into the energy systems and components that make up the state's electrical grid provides significant findings and benefits and identifies future research needs. The Energy Commission funded research and demonstration improvements to the successful microgrid on the University of California, San Diego (UCSD) campus. The system now provides 92 percent of the campus' energy load, and after completion of this project, UCSD's microgrid will have the largest, most diversified portfolio of electricity energy storage and electric vehicle charging stations of any university campus in the world. The campus hosts frequent tours and events to share the research findings with other researchers, businesses, agencies and utilities.

Research successes with synchrophasor technologies—highly complex tools that provide detailed electrical grid information to help avoid system problems—were advanced in 2012 with continued technology upgrades, and efforts to increase wider adoption of synchrophasors, and integrate the data they provide with other system tools. As a result of 2012 improvements, California's grid operator sees changes more clearly, compares data more effectively with interconnected systems outside the state, and is better capable of coordinated responses to any event or problem on the grid. By 2020, the effects of PIER synchrophasor research and related applications will save Californians an estimated $210 million to $360 million annually by improving reliability and avoiding costly outages and will provide $90 million per year in other economic benefits.

Program Status and Future Research Directions

The year 2012 was a transition year for the PIER program. In 2011, the Legislature did not reauthorize the electricity research portion of the PIER program and the mechanism under Public Utilities Code Section 399.8 for funding it, the Public Goods Charge. As a result, the PIER Electric program will cease to fund new RD&D projects after available funds have been encumbered. In 2012, the Energy Commission issued the final solicitations for PIER Electric funds. Contracts will be awarded in spring 2013 and active projects will continue to be managed by the Energy Commission through 2015.

In 2012, the Energy Commission continued to solicit, gather, analyze, and respond to the feedback provided by its research partners, other agencies, utilities, and industry. Staff actively engaged with stakeholders in developing Commission RD&D activities and shared research results through forums, workshops, collaborative partnerships, online media, and other means. The solicitation and contracting process underwent improvements to increase administrative efficiency, keep PIER funds in California, contain contractor administrative costs, and increase competitive selection.

The Energy Commission recommends that public interest energy research continue in the future to focus on:

- Developing and demonstrating energy efficiency technologies and informing future building and appliance efficiency standards.
- Demonstrating zero-net-energy buildings (highly efficient buildings that meet their annual energy needs with on-site renewable generation) and energy-smart communities.
- Increasing energy efficiency in major energy end-use sectors, including buildings, industrial, agricultural, and water sectors.
- Advancing and demonstrating demand response and energy storage technologies and incorporating these technologies to create a statewide smart grid infrastructure.
- Developing renewable technologies and community and utility-scale renewable generation, and accelerating integration of renewable energy into the state's electricity grid.
- Advancing smart grid capabilities to allow electricity systems on the utility- and micro-scale to flexibly integrate multiple energy sources, store energy, run demand response processes, and support interconnected grid systems.
- Supporting energy-related environmental research and transportation energy research directly tied to energy generation, transmission, and use.

Under the Energy Commission, public interest has been and remains the paramount guiding theme in administering RD&D ratepayer funds. Arguments have been made, and history shows, that moving the administration to a nonpublic entity would narrow the focus to private, market-driven profits. Publicly administered RD&D ensures transparent and accountable data and research results, a balanced portfolio, maximum leveraging of funds with private and other government entities, and direct accountability to the public, ratepayers, and the Legislature. The administrators of any public interest energy research program should be held to these same goals and standards. It will also be incumbent on the administrator to coordinate the research portfolio with the California Public Utilities Commission, California Air Resources Board, utilities, and other stakeholders to avoid duplication and capture synergies.

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CHAPTER 1:
Introduction and Overview

The Need for Energy Innovation

Economic vitality and social well-being depend upon affordable, safe, and reliable energy. The way society uses energy has evolved radically and has transformed the modern world, both economically and physically. Energy markets are vastly different today than they were just decades ago; use of finite fossil fuels has created not just environmental problems but investment risks and uncertainties. For all of these reasons, investing in energy innovation is absolutely critical to a bright future for California and the world.

For example, an electric system powered mainly by natural gas, oil, and coal has little need for advanced storage technologies. But energy from renewable sources like solar and wind cannot be stored in a barrel or tank. These sources produce electricity that must either be used immediately or stored using advanced batteries, compressed air storage, hydro storage, or other methods, many of which are relatively complex and new. Increasing the level of renewable energy sources will require significant technological innovation in storage technologies and large scale deployments to balance the influx of renewable energy into California's electric grid. And this innovation must happen quickly.

Modernizing and improving energy systems preserves resources, creates jobs, and can solve environmental problems. The people's elected representatives have set standards to improve efficiency, reduce global warming emissions, and increase renewable energy use, among many others, with required deadlines quickly approaching over the next several decades. These policies along with a growing level of private and federal investment point towards a diverse and low-carbon energy future. But the sheer scale of the challenge means that coordination among technical, economic, and policy realities will be necessary.

For California to achieve the standards set by the people's representatives, energy innovation and infrastructure investments are necessary

The Role of Public Interest Energy Research

California will make the leap from the status quo to achieving its goals at the lowest possible cost only by investing in innovation. While public interest energy research alone cannot provide the entire investment, its role is indispensable. The California Energy Commission's Public Interest Energy Research (PIER) Program has invested in research, development, and demonstration (RD&D) in the areas of energy efficiency and demand response, renewable energy resources, advanced electricity generation, transmission and distribution, energy-related transportation, and energy-related environmental research.

Public policy actors have compelling power and responsibility to invest in energy research for several reasons. Firstly, energy infrastructure decisions have a broad impact on public safety and the economy. Communities and businesses on the United States' East Coast were left without power for weeks and in some cases for months, after "superstorm" Hurricane Sandy in October 2012. This event was only the most recent illustration of the vulnerabilities of highly centralized and interconnected electric grids and of the value of new tools to strengthen system resiliency. PIER addresses these vulnerabilities by directly investing in grid solutions that have significantly improved electricity reliability as follows: PIER smart grid and microgrid projects on a California university campus, at the state's third largest jail, and in partnership with an investor-owned utility have demonstrated that these energy systems can reduce pressures on the larger electric grid and provide more power security in the event of outages by operating independently. Advancing these solutions will help reduce the impacts of electric system disruptions in California and provide customers with more reliable service. It will also help California meet distributed generation policy targets.

Effective public energy RD&D investments drive, attract, and enhance private sector investment.

Secondly, California has unique influence upon energy decisions elsewhere due to its status as one of the largest and most innovative economies in the world. California's efficiency standards and environmental policies, and the technological advancements produced by its hubs of innovation, have verified many times over the saying "As California goes, so goes the nation." Raising the bar for energy efficiency, safety, and reliability for California ratepayers often leads to the same improvements outside the state.

But regulations are not enough, nor can public investments overcome all the barriers faced by new energy technologies. Public energy RD&D is a crucial link between researchers with an idea and investors looking for a reasonable prospect of return on their investment. PIER supports higher-risk experimental research with the potential for providing a public benefit, thus reducing private sector risk by helping demonstrate and prove the technical potential of a new idea. PIER also helps new products and practices overcome common market barriers through demonstrations, permit streamlining, incentives, goals and standards, and by making effective technologies directly available to sector end users. The Energy Innovation Pipeline demonstrates the process that brings the products of energy research to energy users— and California closer to its energy goals.

Figure 1: The Energy Innovation Pipeline Brings Technologies to Market

Source: California Energy Commission

Research improves productivity and lowers costs, fostering economic growth. Nobel laureate Robert Solow estimated that more than 90 percent of economic growth comes from investments in innovation.[1] Furthermore, research has public benefits. Economic studies have placed the social rate of return for research, including the benefits of research spillover, at around 66 percent while the private rate of return to RD&D is around 20 to 30 percent.[2] Despite the potential for high returns, firms tend to under-invest in research for several reasons. Firms may wish to avoid paying for innovations that other firms could learn from or partially copy. They may reward their Chief Executive Officers for short-term results than longer-term research outcomes. And firms or lenders may find individual research investments too risky even if the whole set of potential research investments among different firms is nearly sure to pay off well.

Because publicly funded RD&D addresses common public needs together with innovation hurdles, helps reduce risk for private investment, and makes sure policies are reasonable and attainable, it is one of the best links between regulations passed by the state and job-stimulating, proactive investment in California.

Report Structure

The Energy Commission's *Public Interest Energy Research 2012 Annual Report* describes 2012 program accomplishments and benefits, new work initiated, and program updates and enhancements. Chapter 1 provides a program introduction and overview of the policies guiding the Energy Commission's public interest energy research. Chapter 2 describes major research programs and highlights selected electricity research projects and their benefits. Chapter 3 discusses next steps for 2013 and the planned successor program. Appendix A lists the electricity-funded RD&D projects that were initiated or amended to add funds in 2012.

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1 Cited by D. M. Kammen in testimony to Congress, 10/10/2008, "Investing in the Future: R&D Needs to Meet America's Energy and Climate Challenges"

2 Nemet, Gregory F. "Policy and Innovation in Low-Carbon Energy Technologies." PhD Dissertation, May 2007. https://mywebspace.wisc.edu/nemet/web/Thesis.html

Policy, Planning, and Program Overview

As the state's primary energy policy and planning agency, the Energy Commission makes assessments and forecasts to develop energy policies that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety. The Energy Commission sponsors RD&D to support these energy policy and planning needs and to meet the provisions of Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), and the PIER Advisory Board by focusing research intended to:

- Support technology development to enable future building and appliance efficiency standards.
- Increase energy efficiency in major energy end-use sectors, including buildings, industrial, agricultural, and water sectors.
- Develop and integrate renewable energy into the state's electricity and natural gas systems.
- Fund needed advancements in smart grid and energy storage technology.
- Support energy-related environmental research and transportation energy research directly tied to energy generation, transmission, and use.

Public research program administration by public agencies ensures benefits to California ratepayers by:

- Providing transparency and accountability for all funds and projects.
- Providing coordinated research to avoid duplication.
- Providing independent and impartial evaluations of proposals and projects.
- Supporting RD&D work with a statewide, policy-focused interest dedicated to benefiting California ratepayers.
- Generating research opportunities for California-based companies that create jobs and stimulate the economy.
- Building long-standing relationships with California's diverse and substantial research capabilities at state universities, national laboratories, and high-tech companies.
- Leveraging funds with private sources and the federal government.
- Working with the Legislature to ensure the program is operating to fulfill statutory goals.

PIER and Policy: Achieving the Vision for California's Electricity Future

Policy makers have crafted a vision for California's electricity future that is vastly different from its present. Through laws, ordinances, regulations, and standards, the blueprint for this vision has emerged.

The Vision for California's Future:

California's electricity future by 2030 and beyond will be characterized by highly efficient buildings, industries, and businesses, energy generation that is low-carbon, sustainable, and distributed, and a reliable, flexible transmission and distribution infrastructure.

The following table summarizes some of California's major energy policies and standards. PIER funding decisions are strategically made to achieve these goals, and those of many other policies not listed here, at the lowest possible cost and without sacrificing safety and reliability.

Table 1: Select Policy Goals for California's Energy Future

Policy or Standard	Goal
Governor Brown's Clean Energy Jobs Plan	California should produce 20,000 new megawatts (MW) of renewable electricity by 2020, 12,000 MW of distributed energy, and 6,500 MW from CHP
California's Loading Order, from the California *Energy Action Plan*	Prioritizes Energy Commission research investment first in energy efficiency and demand response; second, in renewable energy and distributed generation; and finally, in clean fossil fuel sources and infrastructure improvements
Executive Order B-18-12 – Greening State Buildings	Calls for efficiency improvements in new or renovated state buildings larger than 10,000 square feet; sets ZNE and GHG reduction goals
Integrated Energy Policy Report	The Energy Commission's biannual energy forecasting and assessment report (required under Senate Bill 1389 of 2002) recommends policies to foster the development of energy efficiency, renewable energy, and more
Assembly Bill 32 (2006) - The California Global Warming Solutions Act	Requires the state to reduce greenhouse gas emissions to or below 1990 levels by 2020
CPUC Energy Efficiency Strategic Plan	Sets efficiency goals, including zero net energy goals for new homes by 2020 and for new commercial buildings by 2030
Senate Bill X1 2 (2011) – The Renewables Portfolio Standard	Requires all electricity retailers to meet 33% of their retail sales with renewable energy by 2020

Policy or Standard	Goal
Senate Bill 17 (2009)	Mandates implementing and planning a smart grid
Governor Brown's Executive Order B-16-2012 and the *2013 Zero Emission Vehicles Action Plan*	The Governor's Executive Order sets a long-term target of reaching 1.5 million zero-emission vehicles on California's roadways by 2025 and directed state agencies to "encourage the development and success of zero-emission vehicles." The *2013 Zero-Emission Vehicle Action Plan* identifies specific strategies and actions to meet this goal
Senate Bill 1250 (2006)	Made provisions for efficiency and renewables research, declaring that it is in the best interests of the people of California that environmentally sound, safe, reliable, and affordable energy services and products be developed and that the PIER Program make research investments to this end
The State Alternative Fuels Plan	Recommends actions to meet alternative fuel goals and set a goal of 26% of the fuels coming from alternative sources by 2022

Source: California Energy Commission

PIER Addresses Challenges Facing Policy Goals

By following policy priorities to make funding decisions, the PIER program since its creation in 1996 has effectively ensured that California's energy goals are met. Current energy technologies and practices clearly need efficiency and technology improvements, but the technical challenges often pale in comparison to economic and policy barriers. The diverse and ambitious goals created by California's Legislature and Governor face significant hurdles that are addressed by broad and strategic energy research.

The Breadth and Scale of the Vision: With deadlines for efficiency, renewable energy, smart grid, bioenergy, emission reduction, and many other energy goals quickly approaching, public interest energy research in all of these areas helps ensure each goal can be met. Public research funding initiatives developed openly with relevant stakeholders.

The Need for Coordination: Achieving the vision will require coordination between:

1) Efforts to improve different electricity technologies and practices that will ultimately be used together in the end-use sector, such as lighting, building envelope, and heating, ventilation, and air conditioning, and

2) Innovators, investors, regulators, electricity providers, and policy decision makers to share energy research results and to ensure expectations and goals are kept realistic and efficient. Public energy research provides transparency that can facilitate coordination.

The Need for Directed Investment: Innovations often face uncertainty. Emerging technologies lack the benefit of economies of scale and often need public as well as private investment. With

its record of attracting match funding many times greater than its own funding levels, PIER acts as a funnel for investment into technologies with a high potential for providing benefits and supporting public policy goals.

Making Connections to Market Success: Energy technologies and practices often must be deployed at scale within static infrastructure systems, are often part of regulated markets, and can be highly influenced by social and individual behavior. Thus, the success of a well-established and low-cost technology is often uncertain unless it is directly incorporated into existing energy standards, incentive programs, workforce training programs, or other broad pathways to market. PIER has been a successful implementer of the Energy Innovation Pipeline to bring research results to market which benefits innovators, electricity providers, and ratepayers.

The Energy Commission provides research transparency, accountability, and avoids duplication.

Coordinated Efforts – Natural Gas and Electricity Research Synergies in California

In 2004, the California Public Utilities Commission (CPUC) designated the Energy Commission as the administrator of the CPUC-funded natural gas research program. As the single administrator of public interest research programs for both electricity and natural gas, the Energy Commission leverages the links between natural gas and electricity RD&D in a systems-based approach to advancing science and technology. Funding and benefits are separately tracked, but managing both programs provides a number of advantages. Implementing both natural gas and electric research provides technical and administrative synergies that make both programs more effective, and the coordination provides benefits from the end-user perspective as well.

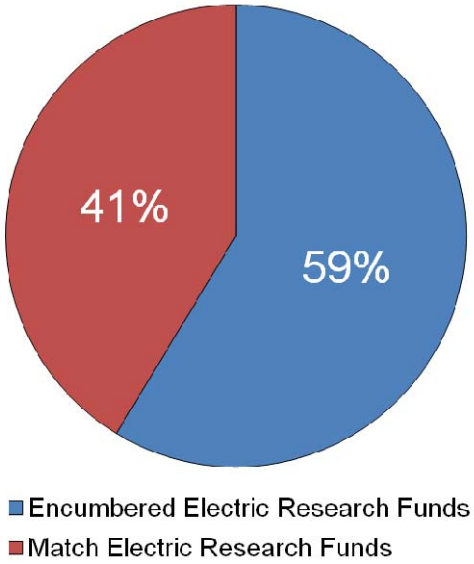
On the technical side, natural gas and electricity research efforts often yield mutually beneficial results. Industrial and residential buildings are powered by both electricity and natural gas, which work in tandem within the building envelope. Some measures have tradeoffs between fuel sources, while others (like building envelope improvements) result in dual savings in both electricity and natural gas, meaning research coordination is logical and itself efficient. Research project synergies often occur as well, such as research designed for sensing the condition of underground electrical cables creating new insights that are now being transferred to research to identify gas pipeline defects. This type of technological synergy improves both electric and gas systems. Customers need safe, reliable energy regardless of the fuel source. Implementing research that takes advantage of the natural connection between these fuel sources ensures that overall benefits accrue to end users.

Administratively, the Energy Commission is able to coordinate and leverage funding among its many California stakeholders, including small businesses, universities, California-based national laboratories, investor-owned utilities, energy technology companies, and energy advocacy groups. This reduces duplication of efforts among partners and helps different programs share applicable research results in the gas and electricity areas.

Program Funding Overview

In 2012, $27.9 million in PIER Electricity funds was encumbered by the Energy Commission for RD&D efforts. These funds were matched with more than $19.6 million in match funding. Figure 2 shows the ratio of 2012 encumbered electric funds to match funds.

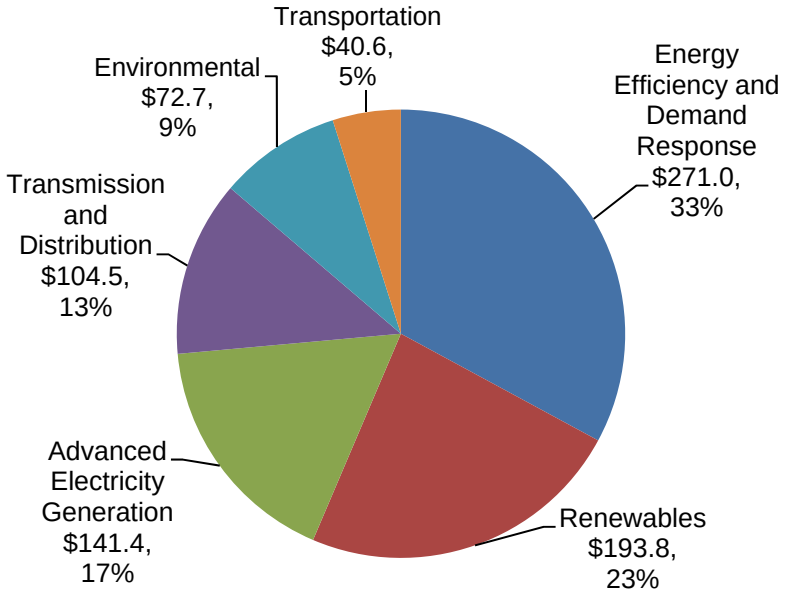
Figure 2: Energy Commission 2012 Encumbered Electric Research and Match Funding



A total of $47.5 million in funding was initiated in 2012.

Source: California Energy Commission

Figure 3: Energy Commission 1997-2012 RD&D Funding Aligns with California's Energy Policies



A total of $839.8 million has been encumbered since 1997. Dollar amounts shown are in millions.
Source: California Energy Commission

As a broad demonstration of the PIER program's effectiveness in prioritizing its projects to align with policy goals Figure 3 illustrates how the PIER program has prioritized projects since 1997 to align with California's loading order. By consistently funding research based on the loading order's priorities, PIER has ensured that energy investments are made where they are most needed to achieve electric system efficiency, generation, and delivery goals.

Attracting Investment to California

To date, the Energy Commission's PIER program has invested more than $839 million in energy RD&D projects and leveraged these investments to attract $1.35 billion in match funding to California. Over 80 percent of the program's research funds were PIER Electric funds.

Bringing Federal Funds to California: In 2012, PIER projects continued to leverage federal funds from the American Recovery and Reinvestment Act (ARRA) of 2009. Though the vast majority of these funds were allocated before 2012, projects with ARRA match funding totaling $13.7 million were approved by the Energy Commission in 2012. In total, Energy Commission RD&D projects have brought $535 million in ARRA funds to California since 2010 at a cost of only $12.9 million of Energy Commission-administered funds. This resulted in not only an enormous investment in energy innovation at a minimal cost to California's ratepayers, but in advancements in crucial energy research areas. For example, ARRA funds supported more energy storage demonstrations in California than have ever been funded at one time in history.

Program Updates and Enhancements

Over the years, the PIER Program has matured and evolved to respond to stakeholder input. The sections that follow describe 2012 administrative activities in support of research efforts and several recent enhancements to the program. Moving forward, these practices and improvements should continue to be part of the administration of any public interest RD&D program.

Stakeholder Outreach and Engagement

In 2012, the Energy Commission continued to solicit, gather, analyze, and respond to feedback from its research partners, other agencies, utilities, and industry. The development process for funding solicitations is transparent. The development of policy plans like the Integrated Energy Policy Report incorporates research results and findings. Project reports and findings are made public through the Energy Commission's website. RD&D staff members coordinate directly with California's investor-owned utilities to share research results and investment plans for future research. Staff and management have participated in many industry and energy innovation forums discussing the state of California energy research. These discussions provide a conduit for research directions and results to reach experts, researchers, and policy makers.

The year 2012 was also characterized by increased interagency collaboration to advise research efforts and reduce overlap. Staff helped develop other agency plans, as in the case of the CPUC's Research and Technology Action Plan to support its *Long Term Energy Efficiency Strategic Plan*. Project management staff also helped convene The Research Roundup, a forum for communication and collaboration among state agencies that perform or sponsor transportation research. The group consists of members from the California Air Resources

Board, the California Department of Transportation, the Office of Planning and Research, the Strategic Growth Council, and the Energy Commission. The goals of the group is to improve collaboration and resource allocation, maximize the impact of state agency transportation-related research efforts, and share institutional knowledge to develop a transportation roadmap for future efforts. PIER's role in transportation research is focused on integrating electric vehicles effectively into the power grid. This type of collaboration demonstrates the value of connecting current research project expertise with state policy and planning functions.

Enhancing Public Outreach Strategies

The Energy Commission considerably expanded outreach and dissemination of research information to the public through various channels in 2012.

The Energy Commission held multiple research forums to share project results, promote collaboration, and seek input on the most valuable next steps, including:

- Potential Pipeline Inspection Technologies for Upcoming Natural Gas Pipeline Research Solicitation Workshop
- Presentation on the U.S. Department of Defense Study: Solar Energy Development on Department of Defense Installations in the Mojave and Colorado Deserts
- Research Breakthroughs: What's Needed to Accelerate Path to Market and Achieve California's 2020 Renewable Energy Goals?
- Staff Workshop on Community-Scale Renewable Energy Development, Deployment and Integration
- Staff Workshop on Solar Thermal Energy Storage and Solar Cogeneration
- Stakeholder and Project Advisory Committees Meeting: Program to Evaluate the Implications of Gas Variability in California
- Technical Staff Workshop on Software for Estimating Fatalities of Bats and Birds at Wind Energy Facilities
- Webinar on Improving Methods for Estimating Fatality of Birds and Bats at Wind Energy Facilities
- Workshop on Potential Research Topic Areas for Upcoming Building Energy Efficiency Solicitation

Staff also participated in or attended the following energy research forums, sharing results and findings with the public and stakeholders:

- PG&E's Zero Net Energy in Context workshop
- Department of General Services' Zero Net Energy buildings workshop
- Stanford University's energy efficiency in residential households meeting
- The Emerging Technologies Coordinating Council (ETCC)'s meeting to discuss current energy efficiency research activities with staff from the investor owned utilities, SMUD and the California Public Utilities Commission

- University of California, Irvine's Advanced Power and Energy's meeting
- ETCC's Technology Resources Innovation Outreach information event for energy entrepreneurs
- United States Department of Energy's (DOE) Annual Energy Storage Systems Program Review Panel
- The Wastewater Biogas Working Group's meeting
- The Association of State Energy Research & Technology Transfer Institutions (ASERTTI)'s 2012 Fall Meeting on Transformative Innovations in Energy Efficiency and Clean Energy Generation
- US DOE's Office of Energy Efficiency and Renewable Energy's Net Zero Energy Communities webinar
- The Sacramento Area Regional Technology Alliance's CleanStart Showcase
- The Silicon Valley Leadership Group's Data Center Energy Efficiency Summit
- Berkeley National Labs Demand Response Research Center (DRRC)'s Technical Advisory Group meeting
- CPUC, PG&E, SCE, SDG&E, and the Division of Ratepayer Advocates' working group meeting on CPUC's resolution regarding Home Area Network Investor Owned Utility implementation efforts.
- Institute for the Sustainable Performance of Buildings demonstration of PIER-funded project to develop a web-based education and training tool in building design
- The California Environmental Protection Agency's America Recycles Day Fair and Expo
- Electric Power Research Institute's Project Advisory Committee (PAC) Using Advanced Power Electronics to Save Energy in Consumer Electronics and Motorized Appliances meeting
- University of California, Riverside Center for Environmental Research and Technology (CE-CERT)'s PAC meetings for the contracts Improved RNG Production by Steam Hydrogasification with Carbon and Alternative Fuels Natural Gas Infrastructure Compatibility
- The Clean Energy States Alliance's Award Webinar: CA Energy Commission Synchrophasor R&D Program and University of California, San Diego Microgrid

The Energy Commission also produced two videos to communicate the benefits and results of important research in new ways: "California's Microgrids: Demonstrating Self-Reliant Energy" and "Built for Efficiency: California's Leading Energy Standards."[3] The Energy Commission included these and other media outreach materials in its overall communication efforts.

3 Available online at: http://www.youtube.com/watch?v=8XksxOZSJOU and http://www.youtube.com/watch?v=-TEFVDRgg2c.

Figure 4: Community and Stakeholder Engagement in 2012

In 2012, the Energy Commission expanded its outreach and awareness efforts; documenting ongoing research and oversight, participating in community and energy events, and producing new media materials to share research advancements –and benefits—with stakeholders and the public. From top left: Energy Commission staff oversee a biogas project during a site visit, shared via the Commission's Facebook page; Commission Chair and R&D lead commissioner Robert B. Weisenmiller meets servicemembers after speaking at an event about the Navy's use of biofuels and the Energy Commission's partnership with the Navy; Staff visit the site of a grid-connected storage system project; A video describing the successful microgrid project supported by PIER; Energy Commission staff describe funding opportunities and research efforts to energy entrepreneurs at an innovation forum.
Source: California Energy Commission

Contract and Solicitation Updates: Ensuring Direct Investment in California

In recent years, the Energy Commission has greatly expanded its focus on contracting with California-based entities and on using competitive selection processes. These improvements were made in response to stakeholder and policy maker feedback and to increase the program's effectiveness as a generator of California energy investment.

Targeting California-based Entities: PIER-funded solicitations are required by Assembly Bill 2267 (Fuentes, Chapter 537, Statutes of 2008) to give priority to California-based entities (CBEs). A CBE is a corporation or other business form organized for the transaction of business that either:

- Has its headquarters in California AND manufactures in California the product that is the subject of the award,
- Has an office for the transaction of business in California and substantially manufactures the product or substantially performs the research within California that is the subject of the award.

Of California, by California, and for California: public energy research fuels home-grown innovation and benefits ratepayers.

While this requirement is not new, the weight given to CBEs was increased in response to stakeholder input to ensure that more funds are awarded to CBEs and to keep PIER funds in California. This increased focus signals to California's businesses, investors, and energy industry stakeholders that the state is a good place to invest in energy.

Containing Costs: Applicants must also now demonstrate methods for controlling their overhead and administrative costs: beginning in 2012, the Energy Commission added a proposal scoring criteria for the ratio of research funds to administrative costs. This will help contain overhead costs and funnel more investment directly towards research.

Increasing Competitive Selection: The Energy Commission has a preference for using a competitive selection process for PIER research initiatives. The procedures for competitive solicitations follow applicable requirements from the State Contracting Manual, State Public Contracts Code, Public Resources Code, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act. Before releasing a solicitation, staff identifies the specific research, demonstration, or deployment objectives for the solicitation. Solicitation objectives are designed to remove specific clean energy deployment barriers and achieve specific clean energy goals.

Intellectual Property Rights and Royalties

Intellectual property (IP) refers to products of the mind that the law protects, such as copyrights, trademarks, and patents. The Energy Commission manages IP rights for the PIER Program by requiring contractors who sell products developed with PIER funds to pay royalties. More than $5.4 million in royalties have been collected over the life of the PIER

Program. In 2012, the Energy Commission took steps to increase the assessment and collection of royalties by strengthening royalty terms and conditions, reviewing and verifying royalty payments, and contacting contractors to determine whether royalty payments were owed. As a result, the Commission successfully collected more than $550,000 in royalties in 2012. The Energy Commission has also retained a contractor to target past PIER project contractors who may have sold products and not yet paid royalties and actively seek royalty payments in applicable cases.

PIER Program Status

In 2011, the Legislature did not reauthorize the electricity research portion of the PIER Program and the mechanism under Public Utilities Code Section 399.8 for funding it, the Public Goods Charge (PGC). PIER electric funds were allocated to competitive solicitations in 2012 and will be awarded in spring 2013. All active and approved projects will continue to be managed through 2015, but the program will otherwise wind down.

Status of Proposed New Electricity RD&D Program

Recognizing the importance and benefits of public interest energy research, Governor Jerry Brown requested in 2011 that the CPUC take action to ensure that programs like those supported by the PGC are instituted under CPUC authorities and take into account the constructive ideas for program updates that were identified during the legislative process.

Following a deliberative process, the CPUC adopted the Electric Program Investment Charge (EPIC) in December 2011, authorizing the collection of system benefits charges for renewables and research, development, and demonstration purposes. In May 2012, the CPUC adopted Decision 12-05-037, which provides the framework for Public Utilities Commission oversight of the administration of EPIC. The decisions also set the framework for funding investments in applied research and development, technology demonstration and deployment, and market facilitation of clean energy technologies and approaches.

After being adopted by the Energy Commission, the investment plan was submitted to the California Public Utilities Commission on November 1, 2012, for consideration along with the investment plans of the three investor-owned utilities. The current CPUC schedule anticipates considering the plans for approval in summer 2013. If EPIC investment plans are approved, they will support continued energy innovation throughout California.

CHAPTER 2:
Public Interest Energy Research Delivers Ratepayer Benefits

In 2012, the Energy Commission funded RD&D that will address and remove barriers to achieving the state's energy policy goals. This chapter provides overviews of the PIER Program's three major areas: energy efficiency, renewable energy, and energy infrastructure. It includes a short description of each program area followed by illustrative 2012 research project highlights describing the issue addressed, project details, and benefits.

The research projects described were active, completed, or had significant results in 2012. The RD&D projects supported by the Energy Commission fall into varying stages; overall, they make up a comprehensive portfolio of promising, just-initiated research, currently underway research, and completed projects that have already begun to return benefits to California electricity users. The research projects (and accompanying benefits) described in this chapter are labeled with their status in this overall portfolio, either as Ongoing Research with Significant Potential, or as Yielding Beneficial Results.

This chapter also includes several excerpts of in-depth analyses of the benefits of various research efforts in important areas. These analyses make best projections about the future savings provided by technologies supported by Energy Commission research, including estimations of the share of these benefits that will be directly attributable to PIER's role.

The chapter concludes by detailing the job-creation effects PIER research initiatives have had in California, as well as ongoing efforts to stimulate sustainable workforce development in the clean energy sector.

Energy Efficiency Research

California's building, industrial, agriculture, and water sectors consume more than 90 percent of the state's annual electricity, or more than 245,000 gigawatt hours (GWh) annually. As the state's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for reducing energy use and cost, peak demand, greenhouse gas (GHG) emissions, and other harmful impacts associated with the inefficient use of energy. Efficiency is at the top of California's loading order, prioritizing investment in efficiency above other resources. Since "energy efficiency is the least cost, most reliable, and most environmentally sensitive resource and minimizes our contribution to climate change," it is the resource of first choice.[4]

California has historically been successful in keeping per capita energy use low as population increased. Many modern energy efficiency challenges are related to changes in the way people

4 *California Energy Efficiency Strategic Plan, 2011 Update:* http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

use energy. Consumer electronics such as televisions, cable boxes, notebooks, and other plug-in devices are quickly becoming a greater portion of overall use. Advanced technologies are powering globalization and economic opportunity, but modern data centers and other information technology support systems use a significant amount of energy. Addressing these challenges through efficiency, using both common-sense and highly-advanced technologies, will allow California's innovation economy to continue to grow, unburdened by enormous energy costs and energy supply limitations.

California's Area of Expertise: The Golden State has long set the "golden standard" for efficiency, as the first state to enact building and appliance efficiency requirements. PIER's efficiency research and demonstrations have helped prove the viability and cost-effectiveness of measures like smart lighting controls and set the stage for these measures to be included in the state's *2013 Building Energy Efficiency Standards*.

PIER's contribution to changes in these standards directly addresses an issue important to ratepayers and consumers. A 2011 Consumer Federation study about public attitudes towards energy and appliance efficiency standards concluded that nearly all Americans (95 percent) support efficiency increases, and that "the public overwhelmingly believes that improving appliance energy efficiency is beneficial and strongly supports appliance efficiency standards. Those people who are aware of minimum efficiency standards set by the government support them. They are willing to pay more for the product knowing that the additional cost will be made up over time in lower energy bills, and in fact, that they will ultimately save money."[5] Continued energy efficiency improvements are essential to meeting the state's energy efficiency and GHG reduction goals.

The Efficiency Vision for California's Future:

California's electricity future by 2030 and beyond will be characterized by efficiency*: buildings, industries, agriculture, and resource-intensive processes will have reduced their energy consumption significantly, preserving vital electric capacity and reliability.*

PIER's Energy Efficiency program area focuses on developing and demonstrating technologies, strategies, and tools that will lay a foundation for a highly efficient future.

Buildings End-Use Efficiency Research

The buildings end-use efficiency program sponsors research leading to cost-effective performance and energy efficiency improvements in new and existing buildings and their associated components and structures (such as street and parking lot lights), equipment, appliances, and consumer electronics. The program focuses on major energy-using systems, including lighting, heating, ventilating and air conditioning (HVAC) systems, and consumer electronics, and targets the following:

5 Consumer Federation of America. "Public Attitudes Toward Energy Efficiency and Appliance Efficiency Standards: Consumers see the Benefits and Support the Standards." March 2011.

- New and improved products.
- Energy-efficient designs, materials, building techniques, and tools.
- Improved performance and efficiency standards for buildings and equipment.

PIER Investments in Efficiency Research Cut Energy Costs for Ratepayers

In 2011, California consumed 272,600 gigawatt hours (GWh) of electricity and 12.9 billion therms of natural gas.[6] This energy use cost California's ratepayers $39.8 billion[7] and emitted 114.5 million metric tons of carbon dioxide.[8] With California's economy rebounding from the recession, demand for energy is expected to grow. Rather than investing in additional generation and transmission infrastructure, a much more cost-effective alternative is to invest in energy efficiency. Experts often call energy efficiency a "low-hanging fruit" because, in many cases, upgrades quickly pay for themselves by returning lower energy bills to ratepayers. Unfortunately, studies have shown that even where obvious cost-effective efficiency opportunities exist, consumers of energy often do not respond. As a result, market penetration of many energy efficiency technologies is less than desirable. To help maximize implementation of energy efficiency measures, research is needed to support viable and cost-effective efficiency technologies and strategies, understand the rationales behind customers' energy choices, and develop better tools and strategies to implement cost effective choices.

An investment of $27.6 million in efficiency research is estimated to result in $10.1 billion in benefits to ratepayers.

Strategic Research Transforms Standards: The Energy Commission's energy efficiency research program invests its funds to promote efficiency technologies and strategies. The benefits of this effort include enhancements to the Building and Appliance Energy Efficiency Standards, Title 24 and Title 20 of California's Code of Regulations, respectively.[9] Between 2005 and 2013, 17 research agreements were directly responsible for or contributed to 14 changes to these codes. The Energy Commission funded research that contributed to energy code changes for electronic devices such as televisions, external power supplies, battery chargers, commercial outdoor and

6 Energy Consumption Data Management System. http://www.ecdms.energy.ca.gov

7 Assuming an average price of $0.13 per kWh (http://www.eia.gov/electricity/sales_revenue_price/xls/table4.xls) and $0.84 per therm (http://www.eia.gov/dnav/ng/NG_PRI_SUM_DCU_SCA_A.htm, calculated using a sector-weighted average)

8 Of this, 46 million metric tons came from electric facilities: http://www.arb.ca.gov/cc/reporting/ghg-rep/reported_data/2011_ghg_emissions_summary_revised.pdf and 68.5 million metric tons from natural gas consumption, assuming 5,307 metric tons CO2-equivalent per million therms.

9 Title 20, Division 2, Chapter 4, Article 4, Sections 1601-1608; Title 24, Part 6.

indoor lighting, residential roofing materials that reduce the cooling load of homes, heating, ventilation, and cooling system improvements, and residential hot water pipe insulation.

An Efficient Investment: The Energy Commission invested $27.6 million[10] in building and appliance efficiency research that contributed to these code changes. Approximately 82 percent of this research was funded by the PIER Electric program, with the remainder funded by the PIER Natural Gas program. Collectively, the projects attracted $7.4 million[11] in match funding, 99 percent of which went to the PIER Electric-funded projects.

These 14 changes to the building and appliance energy codes will save ratepayers an estimated $10.1 billion in total savings between 2005 and 2025. [12] This amount consists of energy savings minus compliance costs. Figure 5 shows annual ratepayer savings resulting from increased energy efficiency. More than 90 percent of the energy savings during this period will accrue to electricity ratepayers. As shown in the figure, savings from research-guided efficiency standards far exceed implementation costs. These savings will increase as California's economy continues to grow.

The total benefits between 2005 and 2025 consist of 122,600 GWh of electricity savings and 1.1 billion therms of natural gas savings. In 2005, annual net savings to ratepayers was roughly $3.9 million. Net savings have expanded and will continue to grow, reaching an estimated $1.9 billion annually by 2025. While future savings are difficult to estimate precisely, it is certain that savings will continue to grow after 2025 as the measures disseminate further and California's economy expands. Relative to the initial investment, PIER energy efficiency research is on track to generate an enormous return for California's electricity ratepayers.

10 This is the nominal figure. The inflation-adjusted equivalent in 2012 dollars is $33.8 million.

11 This is the nominal figure. The inflation-adjusted equivalent in 2012 dollars is $9.2 million.

12 In 2012 dollars, time-discounted at a rate of 3.5 percent. Staff economic analysis is based on Codes and Standards Enhancement (CASE) studies, previously reported data, contractor data, and Energy Commission price forecasts.

Figure 5: Ratepayer Savings Resulting From Standards Informed by PIER

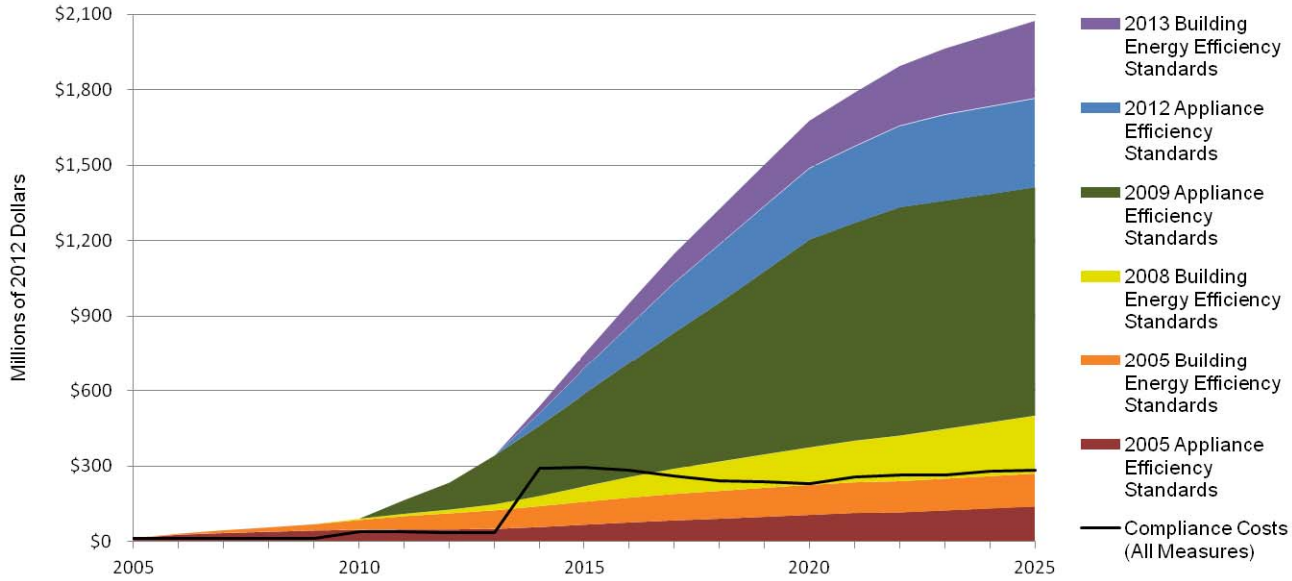


Figure 5 shows the savings (reduced energy bills resulting from decreased energy use) to California ratepayers from updates to Building and Appliance Energy Efficiency Standards. Most of these savings—over 90 percent—will go to electricity ratepayers. The black line represents the estimated cost of standard compliance. The net savings over this 20 year period are estimated to be $10.1 billion, a figure that vastly exceeds the amount invested by PIER in research contributing to these updates.

Source: California Energy Commission

In-Depth Benefits Analysis: Building Performance Tracking

Staff Analyses of Technology RD&D and its Ratepayer Benefits

Where possible, the Energy Commission conducts in-depth analysis of the benefits provided by innovations in energy technologies. One of the many beneficial investments made by PIER has been in low-cost methods to improve the energy efficiency of California's buildings. This section provides an overview of the current and projected future benefits provided by building performance tracking.

The Issue: Much as ships are commissioned, with their equipment tested and their crews trained, buildings can be commissioned to ensure their energy-using systems operate as intended. This energy-saving practice has until recently relied heavily on test protocols and computer models to produce energy savings estimates and has been unable to ensure that savings persist over time. In the mid-1990s, California utilities collaborating through the California Institute for Energy Efficiency (CIEE) developed and piloted a new paradigm of building performance tracking that included performance monitoring and enhancement.

The Research and Current Benefits: Under this paradigm commissioning occurs continuously based on ongoing energy use measurements and diagnostics. The collected information is used to adjust building operations, maximize ongoing savings, and identify new energy efficiency strategies.

PIER funded several projects to demonstrate, benchmark, and evaluate several approaches to building performance tracking. One project with CIEE, in collaboration with the Lawrence Berkeley National Laboratory, performed monitoring-based commissioning (also referred to as MBCx) at several University of California (UC) campuses through the PIER-funded State Partnership for Energy Efficient Demonstration (SPEED) Program and The University of California, California State University, and Investor-Owned Utility Energy Efficiency Partnership. This project achieved 50 GWh annual savings in California by 2011, with another 52.5 GWh targeted for 2012.[13]

Other PIER projects funded private innovators such as Field Diagnostic Systems, Inc., and Ezenics, Inc. to develop technologies and software to implement and bring down the cost of identifying suboptimal equipment performance (or "fault detection and diagnostics"). These projects have led to private sector implementation of building performance tracking in California that is expected to save 20 GWh per year, in addition to out-of-state savings.[14]

Assuming half of the 2012 UC targets were achieved, and through the implementation of building performance tracking in private facilities through FDSI, Ezenics, and others, California ratepayers are estimated to save $11 million a year from building performance tracking. This includes estimated savings of 88 GWh and 4.8 million therms and the avoidance of 53,000 metric tons of carbon emissions and 16 MW of peak load.[15]

Extending Demonstrations and Market Impact: Market penetration of this technology – the proportion of commercial building floor space with performance tracking – has reached 1.3 percent, and the adoption of building performance tracking is accelerating. It is considered to have considerable growth potential because it has been demonstrated to be technically and economically feasible in large buildings (more than 50,000 square feet), which comprise more than two-thirds of the commercial building stock.[16] Building performance tracking has been incorporated into utility incentive programs, is a good strategy for making commercial

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13 Anderson, Mike, Karl Brown, Andrew Meiman. "Monitoring-Based Commissioning: Tracking the Evolution and Adoption of a Paradigm-Shifting Approach to Retro-Commissioning." Newcomb Anderson McCormick, California Institute for Energy and Environment, University of California. Published in Proceedings of the 2012 ACEEE Summer Study (Panel 4 Paper 1130).

14 Staff research and calculations using contractor and independent data; 18.4 million kWh of these savings were identified in a PIER project detailed later in this section under the project title "Advanced Technologies to Optimize Building Efficiency Without Expensive Retrofits."

15 This $11 million is the average net value in an uncertainty interval lying mostly between $8 million to $14 million. Savings estimates are based on continued savings of these projects which the Energy Commission conservatively expects will occur, and the value of those savings is calculated using available cost metrics drawn in repeated random simulations with values near: $0.13 per kWh, $0.68 per therm, $11,000 per MW avoided peak, and $10 or above per metric ton of avoided carbon dioxide emissions.

16 About 71 percent, based on staff calculations using on McGraw Hill data on commercial floor space additions from 1967 to 2010.

buildings more energy efficient, and could lead to statewide standards by providing clear opportunities for low-cost but sizeable building energy savings as the state moves towards its climate and energy goals.[17]

Future Projected Benefits: The future ratepayer benefits expected in California from building performance tracking include reduced electricity and natural gas use, decreased carbon emissions, and decreased peak electricity load. The annual net benefits (savings minus technology costs) of building performance tracking are projected to grow to between $25 million and $380 million in 2020. By that year, building performance tracking tools and strategies are estimated to be saving annually:

- 220 to 2,400 GWh of electricity
- 5.5 million to 60 million therms of natural gas
- 100,000 to 1.1 million metric tons of carbon dioxide emissions
- 12 to 460 MW of peak load

To estimate the amount of these future benefits, PIER staff developed probability calculations that account for the uncertainty about the future saturation of building performance tracking among commercial buildings by 2020. These calculations used educated assumptions based on research and interviews with experts in the field. The probability calculations over this timeline show saturation ranging from 2.5 percent to 25 percent.

Future Projected Benefits Attributable to PIER: PIER has played a pivotal role in the development and dissemination of building performance tracking. Without PIER funding, building performance tracking's improvement and dissemination are estimated to have been delayed by around five years (and could have failed to occur).[18] PIER cannot claim credit for all the future benefits estimated above, but the portion of the savings attributable to PIER can be estimated by quantifying the extent to which it accelerated the technology.

In the case of building performance tracking this is equal to the expected net benefits minus the net benefits that would have accrued had the technology dissemination been delayed 5 years. By this method, the net benefits attributable to PIER are equivalent in value to $4.3 million to $47 million every year from 2004 to 2020.[19]

The wide range in values of these estimates reflects the uncertainty in projecting future market behaviors, but these estimated benefits still exceed by many times the investment PIER made to demonstrate and evaluate building performance tracking projects.

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17 Assessments by Energy Commission Efficiency and Renewables Division and Energy Research and Development Division staff and by CIEE staff.

18 Assessment by CIEE and Energy Commission staff.

19 Future values are time-discounted.

The Project: Achieving Substantial Savings with Fault Detection and Diagnostics

Portfolio Status: Yielding Beneficial Results

The Issue: The ability of high-performance buildings to achieve their energy efficiency targets based on modeling varies, with many buildings substantially underperforming on energy efficiency when actual energy use is examined. This is due to a wide range of factors, including the way building systems are operated and occupant behavior. This performance shortfall needs to be better understood and corrected so that efficiency "as designed" becomes much more closely related to efficiency "as measured."

The Research: As part of its "Evidence-based Design and Operations" program, the contractor focused on one important area to reduce the discrepancy between as designed versus actual building energy use: fault detection and diagnostics (FDD) for rooftop heating, ventilation and air conditioning (HVAC) systems.

The application of FDD on rooftop HVAC systems on commercial buildings includes a set of test procedures generated by computer algorithms that compare actual to expected data. Discrepancies indicate that system operating faults may exist that reduce performance efficiency and waste energy. Figure 6 shows potential fault detection points for roof-top units.

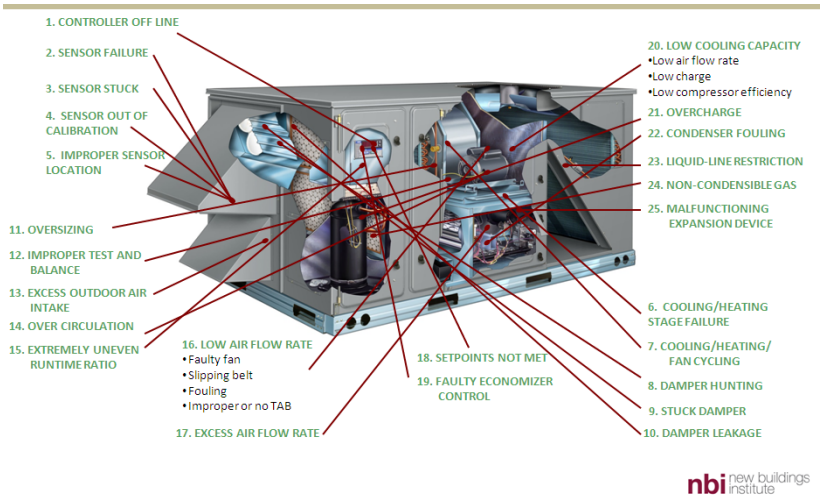
There are several companies that market FDD for unitary HVAC systems and there are equipment manufacturers that are embedding automated FDD capabilities into their products. However, there is no standard method of evaluating the performance of FDD, and this has resulted in uncertainty as to how well the various protocols work.

This project resulted in the development of a systematic approach to evaluating FDD protocols. It includes prototype software capable of carrying out the evaluations and a data library that contains experimental and simulation data for systems operating over a range of operating and fault conditions.

The Benefits: This work advanced industry knowledge of how to reliably measure the accuracy of FDD tools doing measurement of system faults. This will help equipment manufacturers, facility operators, and utility incentive managers make informed decisions on when to use FDD and the protocol(s) that will work best. The work facilitated the incorporation of a mandatory requirement in California's 2013 Building Energy Efficiency Standards (FDD for economizers). The projected first year savings from this mandatory code requirement are 23 million kWh.[20] The protocol evaluation methodology, software tool, and database library of fault conditions for testing the accuracy of protocols/methods from this project will also help develop future energy code enhancements. This can include other types of unitary HVAC system faults for consideration as compliance credit options or prescriptive or mandatory measures.

20 http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/HVAC/2013_CASE_NR_Light_Commercial_Unitary_UPDATED_Nov_2011.pdf

Figure 6: Potential Faults/Malfunctions of Rooftop Unitary System(s)



Source: New Buildings Institute

Agreement Number: 500-08-049 Contractor: New Buildings Institute
Project Cost: $419,00021 Co-funding: $310,000[22] Project Term: June 30, 2009 to March 29, 2013

The Project: Advanced Technologies to Optimize Building Efficiency without Expensive Retrofits

Portfolio Status: Yielding Beneficial Results

The Issue: As discussed in this chapter, building energy systems often do not function as designed due to faults introduced during installation or problems that develop during routine maintenance and operation. Numerous investigations show that lack of quality system installation and maintenance can increase HVAC system energy use by 20 to 30 percent, regardless of their rated efficiency.23 The current practice of recovering lost energy efficiency opportunities relies mainly on professional retro-commissioning services. In response to market demands, significant research on automated diagnostics and optimization for building heating, ventilation, air conditioning and refrigeration (HVAC&R) systems was done during the past two decades with the goal of automating the retro-commissioning process.24 Unfortunately, most of the developed technologies faced resistance since they cannot be implemented in a cost-effective, non-invasive and "plug-and-play" manner.

The Research: The goal of this project was to develop, deploy, evaluate, and demonstrate near-zero-cost, non-invasive plug-and-play diagnostics and optimization technologies that could be immediately adopted by both existing and new building control systems. This project

21 The total contract amount for the "Evidence-based Design and Operations Program" was $1,971,152. The Fault Detection and Diagnostics project represented a portion of this amount.

22 This amount is the co-funding for the entire "Evidence-based Design and Operations" Program.

23 California Energy Commission, 2008.

24 Sensus MI Proposal in Response to RFP# 500-08-503

developed technologies for medium-sized to small commercial buildings that use packaged HVAC&R systems. The project included field testing the technology in 252 Target stores in California. Ezenics (formerly Sensus MI) also partnered with University of Nebraska-Lincoln, San Diego Gas & Electric (SDGE), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), Lennox International, Automated Logic Corporation, and Amazon.

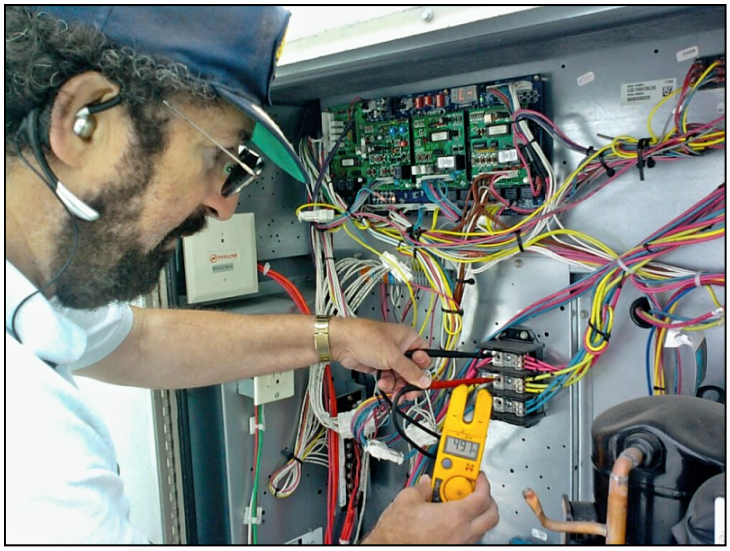
Project research and demonstration results were extensive. The contractor developed and demonstrated a data exchange carrier that established connectivity with an unlimited number of building automation systems to obtain, calibrate, store, and process data in a near-zero-cost manner. Data was continuously stored, analyzed and prioritized into actionable results in the cloud, cost-effectively, at one minute intervals. Ezenics also developed multiple-system-based diagnostics and optimization technologies that addressed the interactions among different systems in buildings, and five low-cost virtual sensors that expanded onboard measurements and enabled these technologies. Overall, the project created an integrated enterprise solution for retro-commissioning buildings in a non-invasive and near-zero-cost manner.

The Benefits: The resulting demonstrations in 252 California Target stores, covering 33 million square feet, were extremely successful. More than 18 GWh and $2.4 million in reduced energy costs were identified between January and December 2012, with additional savings continuously accumulating. Of the $2.4 million, half came from identifying roughly 12,000 HVAC mechanical issues, with the remaining savings generated by 9,000 HVAC control faults ($680,000), 300 lighting faults ($430,000), and 3,000 refrigeration faults. Additional food quality issues were prevented for an additional energy savings of $60,000. Target continues to use this system and plans to approve additional deployments in 2013.

The project has inspired implementations in office buildings, data centers, hospitals, and additional retail locations across the country. The research has enabled additional projects where fault detection and diagnostics results are being integrated with energy rates to drive dynamic adaptive control strategies. Other adopters include Microsoft, Accenture, NetApp, and others with implementation in office buildings, data centers and hospitals across the country. Savings related only to package units on retail facilities have accounted for more than $18.5 million in energy efficiency savings in 2012 alone. Ezenics was recently accepted into a rebate/incentive program with Nexant and a large California utility.

Payback has been shown to be almost immediate upon connection. Ongoing costs for the system are approximately 7 cents per dollar saved. Increased use and demonstration of these low-cost, high-tech solutions to save energy will provide benefits not only to the end users but also to all ratepayers by reducing overall electricity demand, associated carbon emissions, and system pressures. Estimated benefits of technologies in this area were also discussed earlier in this chapter, in the section titled “In-Depth Benefits Analysis: Building Performance Tracking.”

Figure 7: Measurement and Verification Testing



Bob Katin of Katin Engineering (a DVBE contractor), conducting fault verification testing at a Target store in Richmond, California.

Source: California Energy Commission

Agreement Number: 500-08-050 Contractor: Ezenics (formerly Sensus MI)

Project Cost: $1,262,252 Co-funding: $404,041 Project Term: June 2009 to December 2013

The Project: Achieving Savings by Managing Office Plug Loads

Portfolio Status: Yielding Beneficial Results

The Issue: One significant factor complicating estimates of energy use is office plug loads. Office plug load energy use is estimated to be responsible for 23 percent of the electrical consumption in California's commercial office buildings and rise to 30 percent by 2030 Strategies for controlling usage will be critical to meeting the state's future energy efficiency goals.

The Research: This project focused on gathering measured data on office plug load energy use before and after implementing savings strategies to determine their efficacy and cost-effectiveness.

This research project examined office plug loads savings strategies in two commercial buildings, with and without hardware replacement. The plug-load research team inventoried plug load use in a 95,000 square foot public library and a 14,000 square foot small office in California, (both recently LEED-certified). They recorded detailed metered data on a subset of inventoried devices, mainly office equipment, at one-minute intervals for one month to establish baseline plug load energy use. Based on findings from this initial metering, the team installed low- and no-cost energy

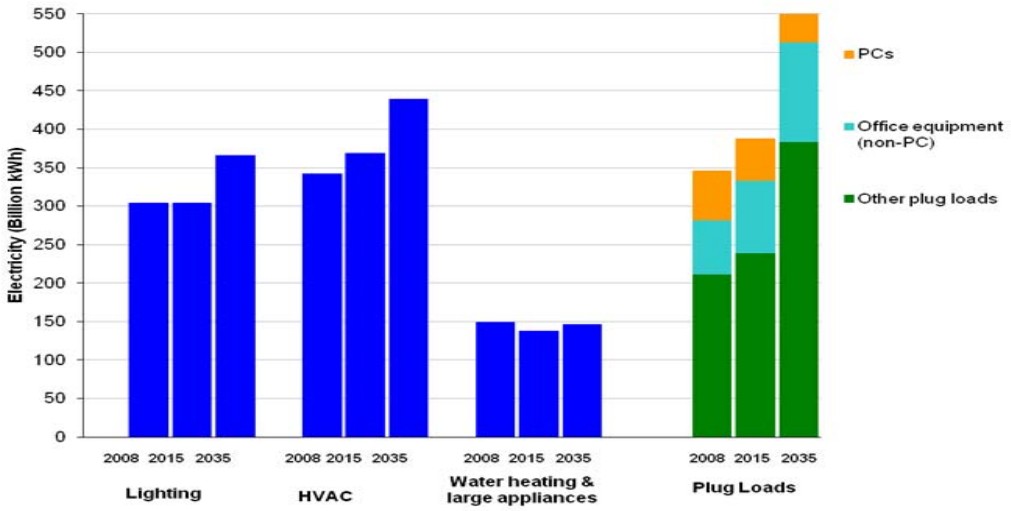
Energy Research Terms:

***Plug Loads** are the electricity consumption of devices including consumer and office electronics, appliances, and some tools – virtually anything that plugs into an electrical outlet and uses some form of low voltage power.*

reduction strategies on a subset of the metered devices, and re-metered plug load energy consumption, on the affected and unchanged devices, for an additional month. Researchers then compared the electricity consumption of the affected plug loads to the baseline data to quantify the energy savings of various measures.

The Benefits: Opportunities for plug-load energy reductions were found in high-performing buildings. By installing upgrades on 39 devices, energy consumption of affected plug loads dropped by 17 percent at one office building and 46 percent at the second office building. These savings represented 1 percent to 3 percent of the total building energy use at the two buildings, respectively. The energy savings for both buildings was 17,450 kWh without hardware replacement and up to 78,480 kWh with hardware replacement. The research demonstrated a 20 to 40 percent reduction in the energy use of office equipment. Reducing small and medium office equipment energy use by 10 percent would translate into an annual savings of 316 GWh.[25] Non-energy impacts include extended equipment life, (and therefore reduced landfill volume and reduced cost for California offices), office comfort due to reduced heat and noise, possibility for downsizing HVAC systems, and space savings due to typically smaller size of efficient equipment.

Figure 8: Plug Loads − The Fastest Growing End-Use



Source: Ecova with data from EIA 2011 Annual Energy Outlook

Agreement Number: 500-08-049 Contractor: New Buildings Institute
Project Cost: $200,000[26] Co-funding: $310,000[27] Project Term: June 30, 2009 to March 29, 2013

25 New Buildings Institute.

26 The total contract amount for the "Evidence-based Design and Operations Program" was $1,971,152. The Office Plug Load project represented a portion of this amount.

27 This amount is the co-funding for the entire Evidence-based Design and Operations Program.

The Project: Low-Cost, Energy-Saving Solid-State Smart Windows

Portfolio Status: Yielding Beneficial Results

The Issue: *Dynamic* or *smart* windows can switch on demand between clear and tinted to block direct sunlight and radiant heat in the summer, transmit radiant heat in the winter, and transmit ambient light from indirect sunlight year-round. This can substantially reduce energy use associated with lighting, and air conditioning in California buildings. Existing dynamic windows have fallen short of the cost, performance, and quality requirements needed for wide-scale market adoption. In particular, currently available electrochromic windows are extremely cost-prohibitive, up to $100/sq. ft.[28]

The Research View, Inc., with support from the Energy Commission, U.S. Department of Energy, and significant venture capital funding, developed a new approach to manufacture electrochromic windows using a production process that is simpler and significantly less energy- and labor-intensive than traditional processes. This new approach allowed electrochromic windows to be manufactured at a substantially lower cost (at a price-premium over standard double-pane windows of less than $15/sq. ft).[29]

The Benefits: View, Inc's electrochromic windows are now commercially available. Compared to standard double-pane windows, electrochromic windows could reduce peak cooling loads by at least 19 percent and lighting loads by 48 percent, offering significant potential savings to California ratepayers.[30] In existing commercial buildings, assuming a 10 percent market penetration, this technology could save California ratepayers more than 500 GWh a year, which translates to more than $65 million annually in lighting energy costs alone. The project also brought $3.47 million in American Recovery and Reinvestment Act funds to California.

28 http://www.nrel.gov/docs/fy10osti/46916.pdf, p. 10

29 Soladigm, Inc. proposal to DOE and Energy Commission

30 http://sites.energetics.com/buildingenvelope/pdfs/58912.pdf, p. 22

Figure 9: Electrochromic Window Tint Levels

View, Inc. windows installed in a standard curtain-wall façade and set to different levels of transparency maximizing daylight while minimizing glare and unwanted heat: Top and left-side windows are set to “clear”; middle windows are set to “full tint”; and right-side windows are set to an intermediate tint state.

Source: View, Inc.

Agreement Number: PIR-10-049 Contractor: View, Inc. (formerly Soladigm, Inc.)
Project Cost: $400,000 Co-funding: $5,779,236
Project Term: February 2011 to August 2012

The Project: Putting Energy Technologies to Work in California − SPEED and Market Facilitation

Portfolio Status: Yielding Beneficial Results

The Issue: Absent real-world demonstrations, emerging technologies often face significant barriers to crossing the ”commercialization valley of death" – the gap between demonstration stage and market entry – and making the market connections that lead to commercialization and widespread deployment. Demonstrations quantify savings and verify that new technologies work, are cost-effective and can be installed in various settings. The development and demonstration of PIER-funded technologies often requires large scale installations in commercial facilities to verify energy and other benefits, technology cost-effectiveness, equipment performance and reliability and market acceptance. Monitored and verified data are also needed to help advance energy-related building efficiency codes and standards. To help California achieve its energy efficiency reduction goals new, advanced technologies must be installed and demonstrated, standardized specifications must be established to ease procurement issues, and energy savings and equipment performance must be verified.

The Research: The State Partnership for Energy Efficient Demonstrations (SPEED) Program works with the University of California, California State University, California Community Colleges, and others to maximize the deployment of PIER-funded technologies. The SPEED program conducts small-scale field demonstrations to prove technical and financial efficacy of the technology on California campuses; once these are verified, the program promotes larger-

scale demonstrations and deployments of these technologies by providing technical assistance, such as energy audits, specification preparation, and monitoring and verification of savings. Large-scale deployment includes campus-wide, multi-campus, or multi-building/facility retrofits. Once large-scale demonstrations are completed and have verified technical and cost-effectiveness, the SPEED program conducts various activities to bring these technologies to market. These include:

- Conducting education and market outreach with existing and potential customers.
- Leveraging partnerships and collaborating on utility and other state/federal energy programs and funding.
- Informing upcoming codes and standards activities for inclusion in future Title 24 Building Energy Efficiency Code updates.

The Benefits: Demonstrating technologies in California brings significant energy, economic, and innovation benefits to the state. The energy savings through demonstrations themselves can be significant. In 2012, the SPEED program completed demonstrations of wireless networked lighting controls at UC Davis and adaptive light-emitting diode parking lighting at UC San Francisco. Demonstrations were initiated for personal comfort systems at UC Berkeley and networked occupancy sensing thermostats in dormitory applications at UC Davis. These demonstrations are intended to verify energy savings and performance and can lead to large-scale deployment of these technologies at higher education campuses and beyond—funded by owners with assistance from state, federal, or utility incentives.

As an example, in 2012, the Energy Technologies Assistance Program completed a large-scale deployment of previously demonstrated PIER-funded technologies. The Energy Technologies Assistance Program is funded by ARRA and the Energy Commission's State Energy Program. The following are the targeted or actual savings:

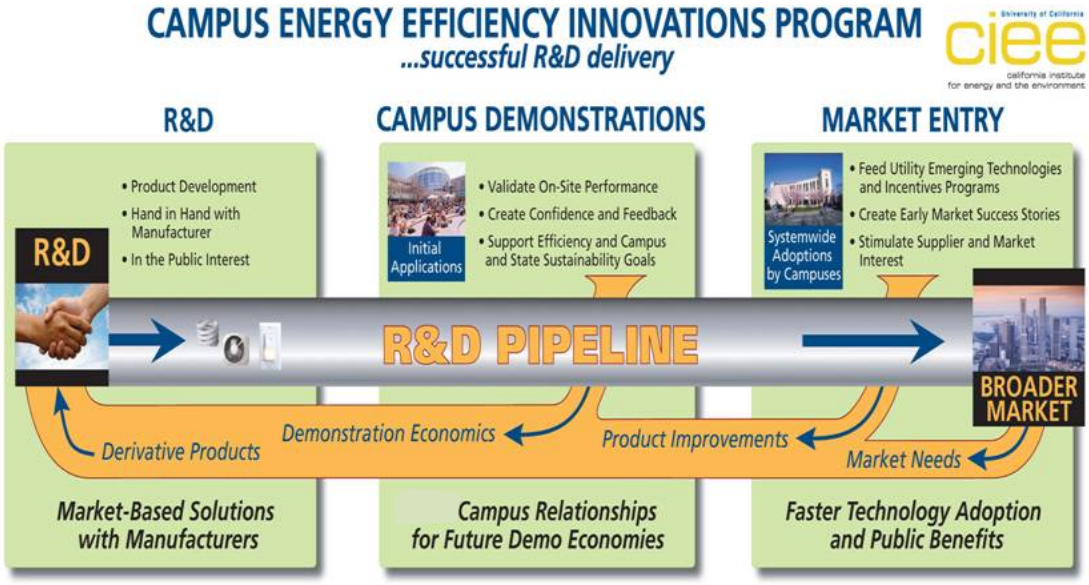
- Lighting and HVAC: Targeted annual savings from this deployment are 23 GWh, 0.95 million therms, or about $3.6 million.
- Wireless controls for data centers: Actual savings were 2.3 GWh (as noted in the section in this report titled "In-Depth Benefits Analysis: Data Center Cooling"), or $240,000 in annual savings.[31]
- 2009-2012 Investor-Owned Utility funding cycle, third-party programs: Estimated annual savings of 74 GWh, 1.9 million therms, or $11 million from scaled deployment of other Energy Commission-demonstrated technologies, such as monitoring-based commissioning (further explored in the previous section titled "In-Depth Benefits Analysis: Building Performance Tracking") and commercial kitchen demand-controlled ventilation.

31 Federspiel, Clifford. Evers, Myah. (Vigilent Corporation). 2011. Recovery Act: Federspiel Controls (now Vigilent) and State of California Department of General Services Data Center Energy Efficient Cooling Control Demonstration. U.S. Department of Energy. California Energy Commission.

Another example of achieving market potential for the demonstrated technologies is the role of the demonstrations in the 2013 Title 24 Building Energy Efficiency Code. Demonstrations of PIER-funded lighting technologies were done in commercial buildings. This included bi-level lighting, lighting controls, and dimmable ballasts. The monitored data of actual savings for these projects proved the viability of the lighting technology in commercial buildings and paved the way for inclusion in the Building Energy Efficiency Code. These technologies contributed a significant fraction of the 25 percent reduction of regulated energy use in new construction attributed to the 2013 Code update.

These standards will reduce future energy use and help California meet aggressive emission reductions and energy efficiency goals. Through collaborative research and demonstration efforts, SPEED and its partners helped bring these new technologies into the market—and bring California closer to realizing its energy goals.

Figure 10: The RD&D-SPEED Pipeline



Source: California Institute for Energy and the Environment

Agreement Number: 500-10-049 Contractor: California Institute for Energy and the Environment (CIEE)
Project Cost: $2,515,918 Project Term: June 30, 2011 to December 30, 2014

The Project: Minimizing Energy Costs and Protecting Air Quality for California Residents

Portfolio Status: Yielding Beneficial Results

The Issue: One-third to one-half of air conditioning loads in residences is due to air infiltration through leaks in the building envelope or other building components like, heating, ventilation, and air conditioning (HVAC) equipment. Up to half of this load could be saved through improved "air tightness" – the extent to which a building prevents air movement through the building envelope—and ventilation systems. However, key barriers to improved air tightness include the difficulty of sensing air losses by occupants and the concern that indoor air quality will be compromised. Currently, new homes in California are required to meet the California Energy Commission's *2008 Building Energy Efficiency Standards* (Title 24) on residential ventilation, which specify minimum continuous mechanical ventilation rates but does not specifically address the issues of infiltration control, energy efficient ventilation, or ventilation load shifting.

The Research: A key goal of this research was to develop ventilation alternatives in homes that preserve or improve indoor air quality while substantially reducing energy costs. Under a "build tight, ventilate right" philosophy, the research evaluated and facilitated improvements to building envelopes; examined both local exhaust fans and whole-house ventilation for energy-saving opportunities; developed methods for commissioning residential exhaust fans, economizers, and other ventilation equipment to ensure they are meeting building standards; created guidelines for retrofitting homes for air-tightness and related measures; and led an effort to integrate the resulting knowledge into codes and standards, both statewide and nationally.

The Benefits: This project addressed both energy efficiency and indoor air quality and provided findings to help tackle both issues simultaneously. This new practical insight will inform potential requirements for residential ventilation systems.

For example, using the standard Time Disability Adjusted Live Year metric to determine health costs, the economic value of improved health was weighted against the increased energy costs of higher ventilation. The study found that for anything but low levels of formaldehyde and acrolein in the home, increasing ventilation above the Title 24 ventilation standard reduced the total cost to the consumer. Better understanding of the health impacts of energy efficiency measures will help ensure that the improvements made while attaining California's energy goals do not have unintended health impacts.

Table 2: Common Indoor Sources of Formaldehyde

Pressed wood products*: particleboard, plywood, medium-density fiberboard (MDF); often used in cabinetry, and wall and floor materials **Consumer Products:** fingernail hardeners, nail polish, wallpaper, some other paper goods, paint, coatings; often a preservative in these and other products **Coatings for Some Cabinet and Furniture Products:** acid-catalyzed urea, formaldehyde type finishes **Permanent Press Fabrics:** clothing, linens, draperies **Combustion Appliances:** wood stoves, gas appliances, kerosene stoves **Tobacco products:** cigarettes, cigars * These sources are being addressed by Title 17 California Code of Regulations Sections 93120-93120.13, adopted by the California Air Resources Board on April 26, 2007

Source: http://www.arb.ca.gov/research/indoor/formaldGL08-04.pdf

Agreement Number: 500-08-061 Contractor: Lawrence Berkeley National Laboratory
Project Cost: $1,688,155 Cofunding: $320,000 Project Term: Start June 2009 and End March 2013

Industrial, Agriculture, and Water End-Use Efficiency Research

The industrial, agriculture, and water (IAW) sectors in California use 30 percent of all electricity consumed annually in the state.[32] These sectors are vital to California's economy and rely on an affordable, reliable, and sustained energy supply. Through RD&D, the Energy Commission seeks to improve the energy efficiency of industrial processes, agricultural operations, and water and wastewater treatment plants. These sectors are also sensitive to the reliability and quality of electric power. Therefore, in addition to improving energy efficiency, the program also researches, develops, and demonstrates technologies that help these sectors deal with power quality, supply, and reliability issues while improving energy efficiency. The major industries include food processing, cement, electronics, e-commerce, petroleum extraction, refining, and production. The sector also benefits from complementary natural gas-funded efforts to develop and demonstrate technologies that enable renewable resource-fueled processes to be substituted for natural gas-consuming processes.

Examples of recent targeted technology areas include:

- Industrial energy efficiency: waste heat recovery, energy-efficient industrial heating, cooling or refrigeration, advanced sensors and controls, advanced burners, innovative combined heat and power (CHP) technologies, industrial process heating or cooling from renewable resources, and demand response.

32 2011 Emerging Technology Demonstration Grant Program Solicitation, PON-11-501, revised October 2011.

- Water and wastewater: energy and water use optimization for water and wastewater treatment, reduction in industrial wastewater, water recycling or recovery of process wastewater, agricultural or landscape irrigation system efficiency.
- Data centers: cooling and energy use reduction and demand response, power management, innovative server designs, equipment and network improvements.
- Customer-side electricity storage: energy storage for peak load reduction, load management or demand response, integration of renewable generation.

In-Depth Benefits Analysis: Data Center Cooling

Staff Analyses of Technology RD&D and its Ratepayer Benefits

Where possible, the Energy Commission conducts in-depth analysis of the benefits provided by advancements in energy technologies. Some of the beneficial efforts made in the Industrial, Agriculture, and Water End Use Program have focused on data center cooling technologies. This section estimates the current and projected future benefits provided by overall innovations in this area. Following this analysis section, two 2012 efficiency research projects related to data centers are highlighted.

The Issue: Data centers consume over 9 billion kWh of electricity every year in California, using more than 3 percent of California's electricity. Much of that energy is used just to keep servers and other information technology (IT) equipment cool. Over the past decade, PIER has funded research that identified the high energy cost of data center cooling, developed a research roadmap to identify research needs to address data center energy use, and funded RD&D and outreach that resulted in the dissemination of intelligent data center cooling technology such as the Vigilent Intelligent Energy Management™ System (VIEMS).[33] This intelligent data center air conditioning control system supplies the right amount of cool air efficiently when and where it is needed, continuously analyzing temperature and humidity readings from a network of wireless sensors throughout the data center.

The Research: The first PIER-funded demonstration and test run of intelligent data center cooling occurred in 2009 at the California Franchise Tax Board in a project led by Lawrence Berkeley National Laboratory and funded through the State Partnership for Energy Efficiency Demonstrations (SPEED). Use of this cooling system control cut total data center energy use 21 percent, saving 475,000 kWh of electricity a year, and provided useful findings to enhance performance and reduce costs of later applications. The intelligent control component alone lowered the cost of chilled water consumption by approximately 14 percent and of fan energy

33 The costs and benefits in this analysis section incorporate the project detailed in the following section titled "Reducing Data Center Cooling Costs with Variable Airflow Management," which describes research that used VIEMS but focused on direct expansion unit applications.

consumption by approximately 60 percent, paying back for the control system in less than two years.[34]

Extending Demonstrations and Market Impact: Informed by this success, the U.S. Department of Energy and the California Energy Commission granted funds to apply intelligent cooling to eight additional State of California data centers. Seven of these are collectively cutting cooling costs 60 percent, while an eighth that lacked variable speed fan drives cut cooling costs 19 percent. Together the eight centers are saving 2.3 GWh of electricity per year.[35] In all, Vigilent customers in the public and private sectors are saving at least 17.7 GWh ($1.7 million) a year in California, and at least 72 GWh a year nationwide.[36] In addition, sales for other providers of data center monitoring and control systems have picked up since the demonstration proved it was feasible and cost-effective.[37] Without PIER's role in identifying the problem, reaching out to industry, and demonstrating viable solutions, experts estimate such technology would have been two to five years delayed in its dissemination to the market.[38]

Future Projected Benefits: The annual projected benefits for these data center cooling technologies take the form of reduced electricity usage, peak load, and carbon dioxide emissions in the state. The annual net benefits (savings minus technology costs) of intelligent data center air conditioning in California are projected to grow from $1.7 million in 2012 to between $10 million and $45 million in 2020.

By that year, the technology is estimated to be saving annually:

- 93 to 400 GWh of electricity.
- 11 to 47 MW of peak load.
- 25,000 to 111,000 metric tons of carbon dioxide emissions.[39]

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34 Bell, Geoffrey, Lawrence Berkeley National Laboratory. Federspiel, Clifford, Federspiel Controls. December 2009. *Demonstration of Datacenter Automation Software and Hardware (DASH) at the California Franchise Tax Board*.

35 Federspiel, Clifford. Evers, Myah. (Vigilent Corporation). 2011. *Recovery Act: Federspiel Controls (now Vigilent) and State of California Department of General Services Data Center Energy Efficient Cooling Control Demonstration*. U.S. Department of Energy. California Energy Commission.

36 Staff calculations based on 2012 savings estimates and data provided by the project contractor.

37 Industry assessment provided by Lawrence Berkeley National Laboratory and evaluated by staff.

38 Industry assessment provided by LBNL and California Institute for Energy and Environment and evaluated by staff.

39 Based on research data acquired from reports and interviews that establish reasonable assumptions about the factors that will affect future growth of intelligent cooling technologies, staff calculated probabilistic projections of the annual savings that will result from these technologies.

Future Projected Benefits Attributable to PIER: The Energy Commission's PIER program has played a quantifiable role in providing these significant benefits to California ratepayers. PIER can claim the benefits provided by this technology to the extent it accelerated the technology; the share of these benefits attributable to PIER is estimated as the value of the expected net benefits minus what net benefits would have accrued had the technology dissemination been delayed two to five years. By this method, historic and projected net benefits attributable to PIER are equivalent in value to benefits of $2.6 million to $14 million every year from 2009 to 2020.

The uncertainty in projecting future market behaviors makes the range of benefit estimates wide, but they still considerably exceed PIER's total investment of $2.3 million in all stages of related RD&D, $660,000 of which was spent specifically on intelligent data center air conditioning.

The Project: Reducing Data Center Cooling Costs with Variable Airflow Management

Portfolio Status: Yielding Beneficial Results

The Issue: Data centers have intensive electricity needs, much of which is due to air conditioning. Data center cooling equipment consists of chilled water based air conditioners and/or direct expansion computer room air conditioning (DX CRAC) units. DX units are common in small data centers and computer rooms where chilled water systems are not cost effective, in large data centers that have outgrown their chilled water supply, or in situations where operators are concerned about potential water leaks. In DX units, compressors are located within CRAC units and provide cooling through expansion of refrigerant from liquid to vapor in cooling coils. In chilled water systems, compressors are located in a central chiller plant that circulates chilled water to cooling coils in CRAC units.

Historically, CRAC equipment, especially DX units, does not use variable speed drive (VSD) fan control. The often-cited argument is that the cooling loads in data centers remain relatively unchanged and therefore VSDs are not economically justified. In 2004, VSD fans were installed on chilled-water CRAC units at an Oracle data center. This demonstration had a payback period of less than six months and now VSDs in chilled-water CRAC units are accepted in the industry. To extend use of VSDs on DX CRAC units, a demonstration is needed to provide the performance, reliability and economic data for market acceptance.

The Research: This project demonstrated the effectiveness of airflow management by retrofitting VSDs to existing DX CRAC units along with a distributed wireless, mesh temperature sensor network to control VSD operation. The wireless temperature mesh network was supplied by VIEMS.

To date, DX units at NetApp and the Electric Power Research Center's data centers in Palo Alto and Sunnyvale, respectively, were retrofitted with VSD fan controls, a wireless temperature mesh network and associated controls hardware/ software. These retrofits were installed and

commissioned and are controlling data center cooling needs (along with the DX unit's fan speed).

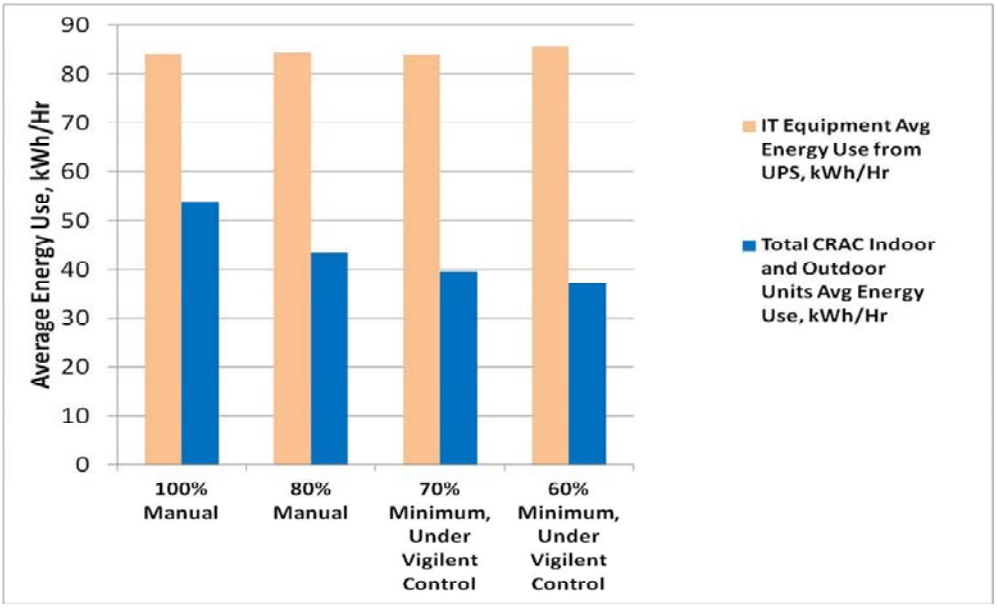
After monitoring equipment and energy performance before and after adjustments to the fan speed and installation of the wireless temperature mesh network, the data show that cooling energy use was reduced. The energy use by the information technology (IT) equipment and the cooling equipment are plotted in Figure 11.

The Benefits: Successful demonstrations at these two locations provide the performance, reliability, and economic data necessary to overcome information barriers for adoption by data centers with DX CRAC units. The results from this project demonstrate that retrofitting DX units, which have a service life of at least 20 years, with VSD can lead to energy and cost savings for the large stock of DX-CRAC units within data centers in California. It is estimated that use of VSDs with the wireless sensor network can reduce data center electricity consumption by 15 percent, with a potential total savings of approximately 854 GWh, and save data center operators $102 million in electricity costs each year.[40]

Figure 11 shows the reduction in energy use when the fan speed changes from 100 percent to 80 percent, 70 percent, and 60 percent. For instance, when the fan speed changed from 100 percent to 80 percent, total cooling energy use was reduced by 19 percent. This reduced energy use by the IT equipment of 12 percent. When the fan speed controller was reset to a minimum speed of 70 percent and 60 percent, the data showed that total cooling energy reduced by 27 percent and 31 percent, respectively. The corresponding reduction in overall IT equipment energy use was 17 percent and 19 percent, respectively.

40 EPRI proposal as submitted under PON-08-006

Figure 11: IT and Cooling Energy Use vs. Indoor Fan Speed Settings



Source: Electric Power Research Institute

Agreement Number: PIR-10-022 Contractor: Electric Power Research Institute
Project Cost: $400,000 Co-funding: $100,000 Project Term: September 2010 to September 2013

The Project: Liquid Cooling Saves Energy and Space for Data Centers

Portfolio Status: Yielding Beneficial Results

The Issue: Data centers and telecom systems consume 3 percent of the state's electricity, or more than 9,000 GWh per year, a figure that has been growing rapidly.[41] The energy used to provide cooling for data centers can be as much as 45 percent of the total energy use. Air cooling is the predominant means for data center cooling, but due to increasing energy intensity of data centers, this method of cooling is becoming more costly and less capable of meeting cooling demand. While pursuing efficiency research to reduce the energy use of data center cooling, the Energy Commission has also researched different approaches to cooling IT equipment. Liquid cooling is more efficient and requires less energy than air cooling, but there are technical challenges to using liquid cooling in a data center.

The Research: Clustered Systems developed a prototype, the Very Dense Liquid Cooled Compute Platform, which is most applicable to data centers requiring high computing performance with limited space. The prototype consists of two server racks each with 12 shelves housing a minimum of 144 modules. The application of liquid cooling to this rack design is estimated to achieve a 17 to 45 percent reduction of energy used for cooling compared to air cooling. Figure 12 shows the server rack, module and cold plate. Liquid refrigerant is circulated

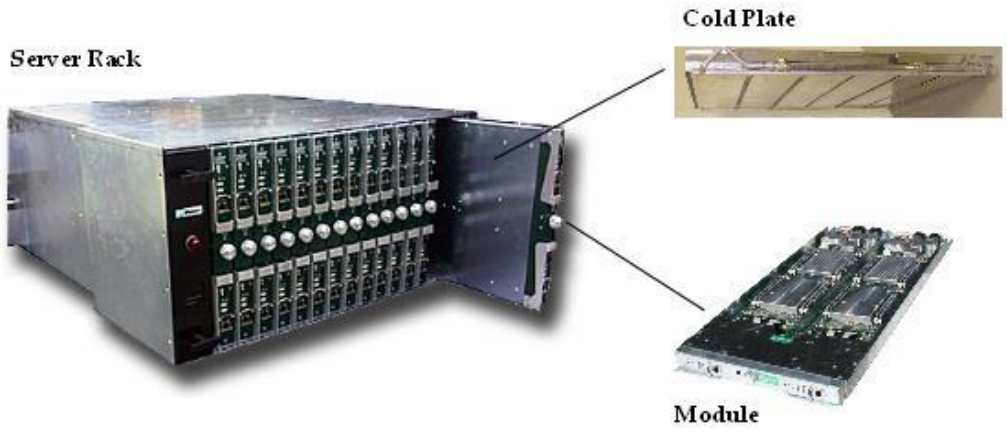
[41] 2007, EPA Report to Congress on Server and Data Center Efficiency, Public Law 109-43

through the cold plate. Figure 13 compares the energy use of air cooling versus liquid cooling using the Clustered Systems technology.

The Benefits: After successful construction and testing of the prototype in 2012, Clustered Systems anticipates the assembly and installation of the first full five-chassis rack at the Stanford Linear Accelerator Laboratory in early 2013. If this technology achieves full market penetration, it could annually save data centers an estimated 700 to 1,800 GWh or $84 million to $216 million in reduced energy costs, assuming $0.12/kWh.[42] In addition to energy savings, the use of liquid cooling will provide savings in infrastructure costs and space. Air cooling requires elaborate ducts, fans, heat exchangers and controls to ensure the cool air reaches the intended target. This equipment is bulky and takes up space that otherwise could be used for additional servers. This infrastructure also requires complex design and planning. Liquid cooling requires a fraction of the volume air does and can be implemented in less complex and expensive applications (for example, a warehouse or similar space as opposed to a dedicated data center). Also, with liquid cooling, server internal fans can be removed—further reducing energy and equipment costs.

The development of this technology brought approximately $2.8 million in ARRA funding to California.

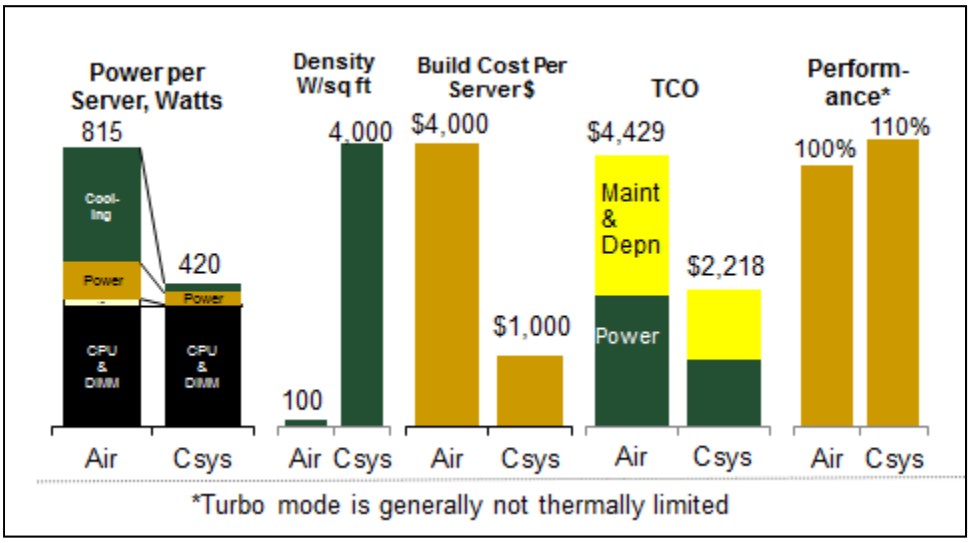
Figure 12: Liquid Cooling Server Rack, Cold Plate, and Server with Heat Risers



Source: Clustered Systems

42 Based on 9,000 GWh per year times the estimated percentage used for cooling (45 percent) times the estimated savings (17 percent to 45 percent).

Figure 13: Estimated Energy Savings and Performance Advantages of the Liquid-Cooled Rack Design



Key: Air= air cooled systems Csys=Clustered Systems TCO= total cost of ownership

Source: Clustered Systems

Agreement Number: PIR-10-058 Contractor: Clustered Systems

Project Cost: $250,000 Co-funding: $2,843,985

Project Term: Feb. 2011 to Feb. 2013

In-Depth Benefits Analysis: Automated Demand Response

Staff Analyses of Technology RD&D and its Ratepayer Benefits

Where possible, the Energy Commission conducts in-depth analyses of the benefits provided by advancements in energy technologies. In California's loading order, energy efficiency – reducing the typical level of energy consumption through system and device improvements—is prioritized equally with demand response, which seeks instead to strategically reduce electricity demand. PIER projects have greatly advanced the state of the art of demand response, and this section estimates the current and projected future benefits provided by overall innovations in this area.

The Issue: If utilities cannot lessen electrical demand during hot summer peak periods, they have to invest ratepayer money in expensive peaker power plants. Demand can be lowered by direct load control, but that limits customer choice during what could be key production periods and could hurt the output of California's businesses. This discourages companies from signing up for utility peak load reduction programs. The alternative is "demand response," which means encouraging customers to temporarily reduce their own demand when needed using event signals, contractual agreements, or price incentives. However, the human intervention required to turn off equipment can make demand response slow and unreliable.

The Research: To support the policy goal of responding to efficient time-sensitive electricity pricing, PIER established the Demand Response Research Center (DRRC) in 2004 at Lawrence

Berkeley National Laboratory. The DRRC developed and demonstrated demand response technologies, determined that they would be optimized if they were automated, and subsequently developed automated demand response (AutoDR) hardware and protocol, along with a communications software application, OpenADR. With these tools, the electricity customer programs equipment to respond automatically to price or contractual event signals, but can override programming if the need arises.

Extending Demonstrations and Market Impact: The use of AutoDR and OpenADR is already avoiding 260 MW of peak load in California annually.[43] With continued PIER funding, AutoDR is being increasingly adopted and the OpenADR communications protocol has progressed from an idea to a standard supported by the U.S. Department of Energy and the National Institute of Standards and Technology under their Smart Grid Interoperability Standards effort. OpenADR is now in use in eight foreign countries, and 60 vendors have built AutoDR logic into their electricity management systems.

Projected Future Benefits: The direct electricity, emissions, and load savings provided by AutoDR and OpenADR are expected to continue to grow. The annual net benefits (savings minus technology costs) of these technologies in California are projected to increase from $16.5 million in 2012 to between $39 million and $118 million by 2020. By then, the technology is estimated to be saving annually:

- 5 to 33 GWh of electricity.
- 365 MW to 1,050 MW of peak load.
- 2,300 to 11,000 metric tons of carbon dioxide emissions.[44]

Benefits Attributable to PIER: PIER can claim the benefits provided by this technology to the extent it accelerated the technology adoption. Without Energy Commission leadership and funding, AutoDR development and dissemination would likely have been delayed around five years, perhaps longer, had it come to market at all.[45] This is in part because product and market research and testing, as well as policy support, were needed. Also, the lack of a standardized communications protocol would have slowed development, raised customer costs, and limited

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43 Beinert, Rolf, "Enabling the Standard for Automated Demand Response." presented at Connectivity Week 2012. Retrieved at http://www.pointview.com/data/2012/05/55/pdf/Rolf-Bienert-ISAEHDDT-16182.pdf.

44 To estimate the current and future benefits of AutoDR and OpenADR, staff interviewed experts in the field both at the DRRC and at companies at the forefront of AutoDR enabled technology. Based on research data collected and using probability calculations that rely on uncertainty assumptions developed from interviews and the research, staff has estimated the savings attributable to AutoDR and OpenADR.

45 Based on interviews with automated demand response experts, a literature search confirming that DRRC was the innovator and leader in the scholarly articles related to automated demand response, and the history of the Energy Commission's role in the push for real time pricing and automated demand response.

customers' ability to change vendors. Thus, the share of net ADR benefits attributable to PIER is estimated as the value of the expected net benefits minus what net benefits would have accrued had the technology dissemination been delayed around five years.

By this method, PIER's investment saved ratepayers and customers between $11 million and $20 million in 2012 and is projected to be saving $15 million to $82 million annually by 2020.[46] The range of predicted savings is wide due to the uncertainties inherent in forecasting into the future; regardless, these values greatly exceed the investment made by PIER, which spent around $5 million over eight years on research, development and demonstration of AutoDR and OpenADR.

AutoDR offers additional promise in helping to balance the variable load of renewable generation technologies. When the wind stops blowing or the sun goes behind a cloud, limiting wind or solar power respectively, other technologies must be used to meet electrical demand and maintain grid stability. Initial tests have shown that AutoDR can be used to adjust electrical demand to compensate for some of the lost sun or wind power. Should AutoDR be used for this purpose, future potential savings, measured in avoided storage costs, are estimated to be $70 million to $165 million per year by 2020.

46 Energy Commission staff calculations based on probabilistic analysis using data from a variety of sources.

Renewable Energy Research

One of the building blocks that will be required to construct California's energy future is the increased use of renewable sources of energy. Multiple state-level policies require California to bolster its renewable energy portfolio. Physical realities increasingly indicate renewable energy will be more secure, have fewer environmental impacts, and will become more cost-effective as technologies improve in the future. Because California's policies and future energy security depend on renewable sources of energy, and thus on innovation, the Energy Research and Development Division's Renewable Energy Program conducts research and development that addresses key technological, performance, and integration barriers of core renewable resources such as biomass, solar, wind, and geothermal energy.

While California builds its renewable energy portfolio to attain its envisioned energy future, it must also support its legacy of visionary environmental policy goals. The energy-environment nexus is clearly rendered in the pursuit of improved renewable energy technologies: while solving one set of environmental concerns, California must not cause another. The energy permitting process is often delayed by environmental concerns and policies, and to facilitate efficient and well-planned siting of renewable energy in the state, the Renewable Energy Program also pursues strategic environmental research projects related to energy.

In addition to representing productive partnerships among state and local permitting authorities, environmental and industrial interests, and others involved with the energy-environment nexus, the efforts detailed in the Energy-Related Environmental Research section signify the importance of a state-level public interest energy research program: California's natural environment is no more unique than its policy and legal environment, and thus the state needs endemic energy research and policy planning efforts. Through these efforts, California can build towards an environmentally responsible renewable energy future.

The Renewables Vision for California's Future:

California's electricity future by 2030 and beyond will be characterized by renewable and clean generation*: low-carbon, sustainable, local, and diverse power resources will make California's power portfolio more secure, independent, and flexible.*

Renewable Energy Research

The Project: Forecasting Technologies to Boost Solar Energy Production in the Golden State

Portfolio Status: Ongoing Research with Significant Potential

The Issue: California's Renewables Portfolio Standard (RPS) calls for a dramatic increase in renewable energy generation in the coming years, and a significant portion of that new capacity is expected to come from the state's abundant solar resources. As discussed elsewhere in this report, one of the critical challenges to greater penetration of utility-scale renewable energy into the state's electricity system is the variability of energy production associated with solar photovoltaic (PV) plants. The California Independent System Operator (ISO) identified

improved forecasting as a top priority for enabling the cost-effective integration of solar energy into the state's electric grid. Without technology and forecasting improvements, variable renewable energy could pose challenges for California's grid planning and electricity operating system, result in costly outages, and may impose additional costs and operational burdens on utilities accepting the renewable power.

To accurately predict energy output for solar photovoltaic systems and ensure the reliability of the grid, it is necessary to provide a set of forecasting, modeling and analysis tools for California that provides the highest possible performance for time scales ranging from minutes ahead to hours and several days ahead. Currently, there are a variety of approaches that offer solar forecasts for specific time frames; however, there is a significant need for an integrated forecasting approach that maintains high accuracy across all timescales.

The Research: To address the variability of solar energy generation, a number of organizations developed a variety of novel modeling and forecasting techniques, each enhanced for a specific time scale and application. Most recently, the Energy Commission funded a suite of three projects that look to take the next step of integrating complementary forecasting techniques with advanced modeling tools and verifying them compared to real-world PV installations. The specific goals of these recent forecasting projects are:

- **Application of a Solar Forecasting System to Utility Sized PV Plants: Forecasting on Three Time Scales -** AWS Truepower will develop, demonstrate, and validate an integrated forecasting system that can accurately predict solar PV plant production on timescales ranging from 15 minutes to two days ahead. This integrated system will be composed of ground-mounted total sky imaging technology for short-term events, satellite-based cloud vector analysis for hours-ahead forecasts, and a computer-based numerical weather prediction model to determine days-ahead forecasts. The integrated tool is expected to be more accurate than any one of the individual approaches across all timescales.

- **Demonstration and Validation of PV Output Variability Modeling: Quantifying and Assessing Existing PV Resources in California -** Clean Power Research will develop a master solar PV database that includes all grid-connected PV systems in California and validate the solar power output variability for any fleet of PV systems. Specifically, this project will expand Clean Power Research's existing PV system technical database to capture 100 percent of the state's grid-connected PV resources, model PV output using a new high-resolution solar irradiance satellite data set, generate time series data to demonstrate compatibility with California ISO systems, and validate the model for PV systems using California ISO's set of measured high-speed plant data.

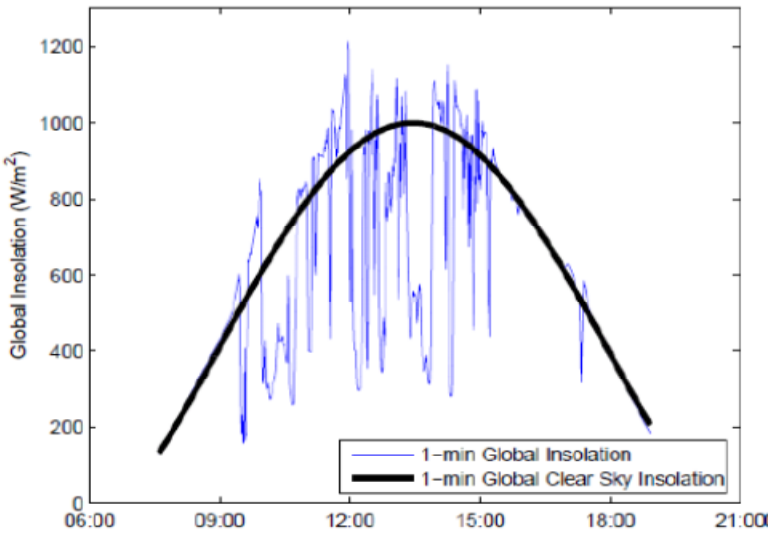
- **Utility-Scale Solar Forecasting, Analysis, and Modeling: PV in the Inland Empire Informing PV Planning Statewide -** EnerNex will gather and analyze intra-hour forecast data for solar photovoltaic production in the Inland Empire region of Southern California. The resulting data will be used to model, monitor, and analyze impacts of adding 500 MW of photovoltaic capacity to the local grid. The forecasting projections

from ground mounted and satellite-based sensors will be validated using known system control and data acquisition information. Results will be used to model solar energy's variability impacts on generation resource planning, utility operations and grid reliability, and the results will be transferrable to system operators across the Western Electricity Coordinating Council.

The Benefits: Each of the above projects is still in the early phases of research, and specific quantitative benefits can only be estimated. However, the results are expected to help minimize the effects of variable generation on the transmission and distribution system, allowing California's ISO to control resources on the grid more efficiently and minimize the amount of added backup generation necessary to maintain grid reliability. Since backup generation, such as natural-gas fired "peaker" plants, is costly to build and operate, any increase in the accuracy of solar forecasting and modeling techniques will translate to a significant cost savings to California's electricity customers.

Furthermore, the Energy Commission has served as a facilitator to help bring together the individual project teams and their respective research approaches. With ongoing guidance from the California ISO, this collaborative effort is expected to result in more synergistic projects that continue to advance the state of the art for renewables forecasting. The Energy Commission's leadership role in managing these efforts will ensure that research results are made available in a public forum and are widely disseminated to a general audience.

Figure 14: Solar Energy Variability on a Typical Cloudy Day versus a Theoretical Clear Sky Day



Source: Lawrence Berkeley National Laboratory

Figure 15: Total Sky Imager, Sample Sky View, and Processed Image

Source: AWS Truepower, Inc.

The Project: Tailoring Renewable Energy Models to Maximize Local Resources

Portfolio Status: Yielding Beneficial Results

The Issue: To address energy usage that contributes to climate change, communities are developing local renewable energy portfolios. Specifying, designing and building such a portfolio, however, is highly complex and time consuming. To launch renewable portfolio projects effectively, the knowledge required to organize data, financial instruments and project descriptions must be standardized and disseminated efficiently. A standardized automated decision-making support tool needs to be developed, tested and made widely available.

The Research: The Sonoma County Renewable Energy Secure Community (RESCO) project builds on the county's climate action plan's aim of reducing greenhouse gas emissions by developing and demonstrating a model that focuses on efficiency measures, demand response together with the integration of a locally owned, cost-effective renewable energy portfolio that delivers self-reliance and economic security to the community.

To understand the impacts of the renewable energy portfolio, Los Alamos National Laboratory developed an integrated computer-simulation tool called Climate-Energy Assessment for Resiliency (CLEAR) to assess and simulate renewable energy mixes supporting low-carbon emission goals and to quantify the key factors involved in implementing a mixed renewable energy resource. CLEAR was developed not only as a model but also as a tool to enable stakeholders and local decision makers to evaluate the potential impact of clean energy deployment strategies.

The following portfolios were developed and analyzed for this project:

- Portfolio 1: Business as Usual, where historical development of resources continues (15 percent local resources).

- Portfolio 2: Mid-case, Local Development augments historical programs. This Portfolio is only possible in the context of a Community Choice program (30 percent local resources).
- Portfolio 3: High case, Community Energy Service Portfolio and Deployment, the preferred portfolio, where state and local policy goals are attained. This Portfolio is only possible in the context of a Community Choice program (50 percent local resources).

Under the RESCO project, the Sonoma County Water Agency (SCWA) implemented renewable technologies at some of its facilities, including a 5 kW wind turbine at the Geyserville Sanitation Zone's treatment plant and a geothermal heat pump pilot project at the Airport-Larkfield-Wikiup Sanitation Zone that uses tertiary-treated wastewater as a heat sink. These technologies add to the existing onsite 500 kW solar photovoltaic and electric vehicle charging stations.

The Benefits: The direct benefits of this RESCO project are the tools and techniques developed that helped Sonoma County identify different scenarios of deploying renewable at the speed and scale required to achieve the greenhouse gas emissions reductions targets set by the county, and subsequently the state goals established by AB 32. Using these tools and models will help local agencies develop renewable energy portfolios that achieve GHG emissions reductions at the lowest possible cost.

Results of the Sonoma RESCO project also feed into the county's other programs, such as the renewable energy program called Sonoma Clean Power. Based on the research team's assessment and analysis of the various ownership models, Sonoma Clean Power would provide a viable option to the development of local renewable energy generation.

The figure below summarizes the potential benefits that can be realized when the designed pilot project under construction at the SCWA facilities is replicated throughout Sonoma County.

The individual projects presented are flexible and scalable to a considerable degree and, if adjusted accordingly, could potentially meet foreseeable contingencies for local electricity needs.

Other communities can benefit from Sonoma County's specific experience and lessons learned by using these tools and similar approaches to develop their own localized and sustainable energy supply portfolios.

Figure 16: Example Portfolio of Renewable Energy Projects

	Project	Capacity (MW)	kWh produced/ saved	GHG savings (metric tons CO_2)	$/ metric ton abated	% of total Water Agency Use	% of total County Energy Use	Total to meet County Load
RE Projects	Farms to Fuel	1.4	12,264,000	9,477	$ 4,326	32%	0.44%	213 Replicas of pilot project RE portfolio
	Wind	0.005	8,203	1.7	$ 17,816	0.02%	0.00%	298 MW Biogas
	Solar	0.5	789,033	159	$ 15,383	2%	0.03%	1 MW Wind
	Total Pilot Project RE Portfolio	**1.905**	**13,061,236**	**9,638**	**$ 4,511**	**34%**	**0.47%**	106 MW Solar
Emission reductions projects	Geothermal Heat Pumps	Efficiency Measure	9,067	1.8	$106,545	Efficiency Measure		
	Electric Vehicles	Overall emissions reduction only, no energy production		4.65	$ 719	Overall emissions reduction only, no energy production		

Portfolio of renewable energy projects planned for Sonoma County with the corresponding capacities, potential benefits, and portion of the county's energy use provided by each generation type. The right-most column shows how many replicas of this kind of pilot project, and the projected generating capacity of each project, would be needed for the county to be powered by 100 percent renewable energy.

Source: Sonoma County Water Authority

Agreement Number: PIR-08-038 Contractor: Sonoma County Water Agency

Project Cost: $1,000,000 Cofunding: $8,403,710 Project Term: 6/30/2009 to 3/31/2013

Advanced Generation Research

Advanced generation research focuses on distributed generation (DG) and combined heat and power (CHP) technologies. This research area supports the technology development for electricity generation from renewable resources and other alternative fuels, with results that cut across the energy efficiency and energy infrastructure research programs. Primary past research initiatives were devoted to increasing efficiency and reducing emissions while addressing the reliability, affordability, maintainability, and durability of power generation systems. A number of technologies were commercialized (or are in the commercialization process) that demonstrate increased efficiencies and lower emissions than proposed regulations in the state.

The Project: New Engine Technologies for California's Combined Heat and Power Market: Vehicle Engines Cross Over to Distributed Generation

Portfolio Status: Ongoing Research with Significant Potential

The Issue: Small-scale combined heat and power (CHP) systems commonly use reciprocating engines that are typically derived from outdated automotive designs. These types of engines have low efficiencies and rely on simple exhaust gas emission control components that have difficulty meeting the California Air Resources Boards 2007 CHP emission standards. These inefficient engines also cause under-sizing or poor usage in commercial applications that have high electric load in comparison to thermal load. Cost-effective CHP systems smaller than or equal to 75 kilowatts (kW) are needed to address significant market populations that have limited CHP options such as motels and restaurants. Advanced and efficient automotive designs – with improved oil control, sophisticated cycle combustion, and better fuel control strategies – are now available, which, when coupled with effective exhaust emissions control components, can offer a possible solution for a cost-effective CHP system that can meet state emission standards.

The Research: This research and development project, implemented by contractor Tecogen, Inc., is re-engineering a modern automotive-type gasoline engine for the small-scale or micro CHP market. The specific objective of re-engineering the engine was to improve engine efficiency by 10 percent, improve heat power ratio by 17 percent with ultra-low emissions, extend service life by 50 percent, and lower costs. An advanced gasoline engine with advanced Atkinson Cycle capability was selected as a suitable model for the CHP, based on the engine's efficiency, high compression ratio, and other advanced features, and based on compatibility with the target output capacity.

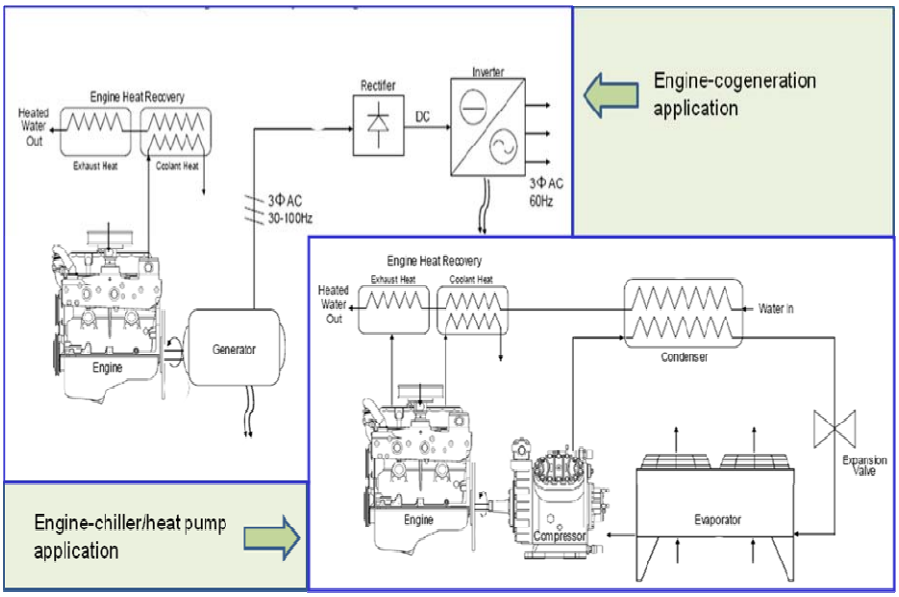
This hybrid vehicle gasoline engine was modified and equipped with a low-pressure natural gas fuel system and extensively tested for efficiency, horsepower and emissions. Parallel to this process, a subsystem was developed that will be integrated with the engine for the combined cooling, heating and power applications. The subsystem is a new high-efficiency heating appliance module that uses a heat pump cycle to produce hot water, while supplementing this output with waste heat from the engine, resulting in an efficiency that surpasses a conventional gas-fired water heater by more than two times. Work is being done to adapt and assess various interface connection points between the engine and the CHP subsystems. Once complete, the engine improvements will make the system more economical to operate and less costly to maintain and will enable growth of the emission-compliant small-scale CHP market.

The Benefits: Extensive laboratory tests, including long term durability tests, confirmed the benefits from the re-engineered engine for natural gas combined heat and power. The engine efficiency exceeded the target of 10 percent improvement, with results showing up to 18 percent gain. Use of dual stage emission control technology that was developed in an earlier PIER project allowed the engine to achieve increase in air/fuel ratio control window and wider compliance margin over the ARB emissions guideline. Overall results demonstrated reduction in natural gas usage, life for emission control catalyst, and reduction in oil usage, leading to lower system costs.

This project supports California's goal to encourage the development of environmentally sound CHP resources and distributed generation. The project will tap into advances made in technologies for engines in the transportation sector and apply them to stationary engines used for small-scale CHP systems. If widely adopted, projected benefits to California ratepayers will come in four ways: 1) Customers with CHP systems would enjoy lower electricity costs, since power is produced more efficiently; 2) All ratepayers would benefit from the associated reduction in GHG emissions and natural gas consumption; 3) The use of natural gas-fueled CHP would reduce growth in demand for central power generation, transmission, and distribution, reducing electricity costs; and 4) The technology reaches a smaller size customer class that now lacks a cost-effective CHP option.

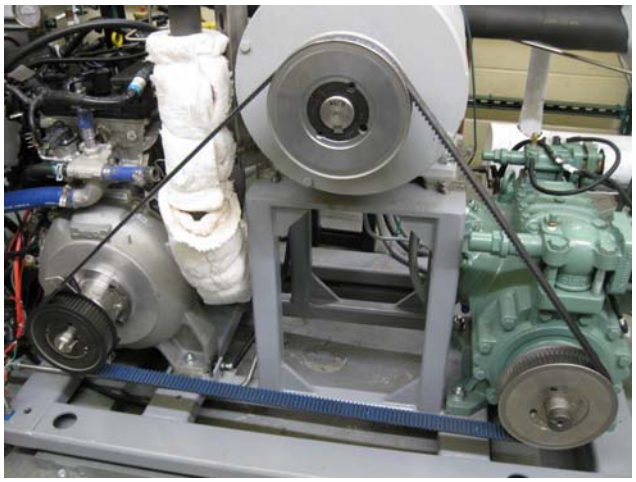
Furthermore, the contractor estimated the benefits to California that can result from this small-scale CHP system. The three CHP product streams targeted for this system, namely, as cogeneration, as heat pump and as chiller, will result in lower natural gas usage (and therefore lower gas costs) as well as lower carbon emissions due to more efficient energy use. By combining the calculated benefits from each of these three areas, and assuming that a cumulative number of 980 units of each of these systems are installed by 2020 and running at 4,000 hours per year, Tecogen estimated that by 2020 the total gas savings will be about 4 million cubic feet or a gas savings value of about $45 million and a reduction in carbon dioxide emissions of about 314,000 tons.

Figure 17: New Engine Technology and Targeted CHP Applications



Source: Tecogen, Inc.

Figure 18: New Engine and CHP Subsystems Development



Left: The engine driveline along with the engine, compressor and generator. Right: The engine endurance test cell.
Source: Tecogen, Inc.

Agreement Number: PIR-08-022 Contractor: Tecogen, Inc.
Project Cost: $999,924 Cofunding: $518,712 Project Term: July 2009 to March 2013

The Project: Developing Low Emission Exhaust Quality Controls to Improve CHP Systems

Portfolio Status: Ongoing Research with Significant Potential

The Issue: Combined heat and power systems use a prime mover, such as internal combustion engines or microturbines, to generate electricity and useful heat simultaneously. The heat produced by the prime movers during the combustion process can be used as a heat source for a variety of applications, such as an absorption chiller in a combined cooling, heat and power (CCHP) application. Because these systems use what would otherwise be wasted heat energy, they provide higher energy efficiencies than electricity generation alone. The market potential of CHP systems in the 0.1 to 1 MW size class are well documented and have been promoted for many years. However, the actual deployment of CHP systems in this size class has fallen short of market adoption goals and opportunities.

Two key implementation challenges in the deployment of these CHP systems are 1) meeting the 2007 California Air Resources Board (ARB) emission standards and 2) the inability of a given CHP system to match both thermal and electrical load profiles. In other words, it is generally difficult to optimally match the shifting demands of both electricity and thermal loads with the constant operation of a CHP system. Electric and thermal loads vary due to seasonal operations, site operational and maintenance changes, type of business, utility rates, and other factors. This means that some of the CHP system output can be wasted, especially in applications where thermal and electricity demands peak in the morning and evening but are low at other times.

This project seeks to address these challenges by pursuing the following goals:

- Improve CHP/CCHP system electrical and thermal use efficiency

- Advance a technology that enables CHP/CCHP systems to reduce greenhouse gas emissions
- Match CHP/CCHP system electrical and thermal output to facility needs
- Improve load following capability and operation flexibility
- Improve physical, thermal, and electrical integration among CHP/CCHP systems components
- Improve the efficiency of thermally activated cooling systems that are part of the integrated CCHP systems
- Adopt CHP/CCHP systems to use otherwise wasted fuels and flare gases as system fuels

Energy Research Terms:

Enthalpy *is the measure of total energy available in a thermodynamic system. In this case, it is the amount of energy of the exhaust gas exiting the microturbine.*

The Research: This project is developing a lab-scale exhaust enthalpy control (ExEC) system. The ExEC is an exhaust gas temperature and mass flow control device. It will make recovery of exhaust gas energy easier by 1) increasing or decreasing exhaust temperature by burning additional fuel and 2) maintaining or increasing exhaust gas mass flow rates. The ExEC system will have the capability to measure the quality of exhaust and manage the exhaust temperatures and flow rates, by injecting fuel and tempering air, to match the varying demands of thermal and electrical loads at the site.

The ExEC system will be tested to determine the suitable range of fuel and the range of increase in overall efficiency. The ExEC system will have low-emission, fuel-flexible capability and can be used in systems up to 1 MW in size, although for the purpose of this project, the focus will be on microturbines with an absorption chiller. The project anticipates an improvement from 60 percent to 70 percent overall efficiency and an overall capital cost increase of no more than 10 percent. The project also anticipates meeting and maintaining emissions levels within the ARB standards.

The Benefits: The development of an exhaust control technology that complies with the ARB 2007 emission guidelines will accelerate the deployment of CHP technology into the marketplace because of its ability to 1) improve overall system efficiency, 2) improve flexibility in deployment of a given suite of prime mover/waste heat recovery options, and 3) increase output, extend system life, and reduce payback time. The fuel flexibility – ranging from natural gas to opportunity fuels to hydrogen – will permit placement of the systems in a wider variety of installations. The projected long-term benefits from this technology include:

- **Greater fuel efficiency and reduced emissions:** Reduced fuel use as compared to current consumption levels for power generation and process needs, with an associated reduction in emissions of carbon dioxide.
- **Reduced fuel consumption:** Staff calculations showed potential for about 20 percent reduction in fuel use with a microturbine equipped with an ExEC system when

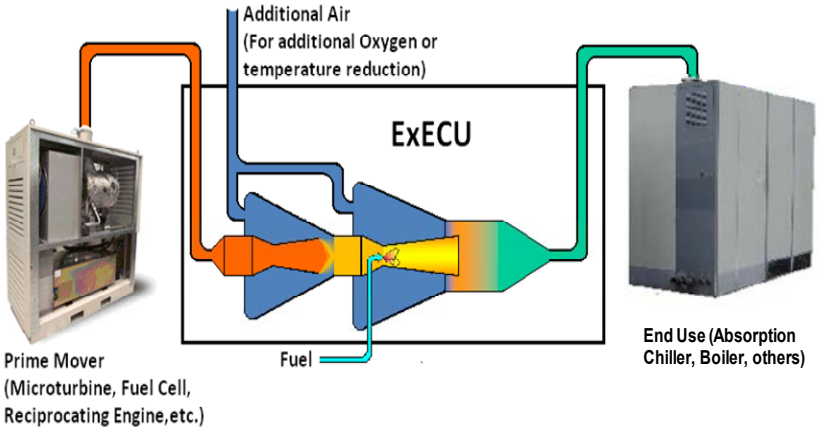
compared to a traditional and comparable-sized boiler for heat, and corresponding carbon dioxide emissions reduction of about 14.5 MMTons per year.[47]

- **Air quality benefits:** Reduced deterioration of basin-wide air quality while meeting increased energy demands as compared to deployment of additional central power plants.
- **Affordability:** Improved reliability and/or reduced costs from additional choices in acquisition of energy, which can trickle down to reduced costs for consumers.
- **Deferred grid costs:** Deferred installation of new power generation, transmission and distribution lines, which has been estimated to have a value of more than $300 per kW per year; if applied to the projected 5,400 MW distributed generation installed capacity statewide, this represents a value of about $1.9 billion.[48]

47 The 2002 California Distributed Generation Strategic Plan, P700-02-002, outlined a goal of approximately 20 percent of incremental power generation increase to be distributed generation. Governor Brown's Clean Energy Plan calls for about 6.5 GW of installed fuel-based DG/CHP to be deployed by 2020 (and total of 12 GW DG including solar, wind, and others) to meet AB 32 Goals. To provide a bound for the application of the ExECU system, assume that the entire 6.5 GW of electric generation would be met with microturbines. Assume the following: with a prime mover fuel to electric efficiency of 28 percent HHV of natural gas: 6.5 GW electric derived exclusively from microturbines = 23.2 GW natural gas consumption; Useful MTG waste heat without ExECU system = ~8.5 GW; Useful MTG waste heat with ExECU system = ~25.5 GW (3 x 8.5); Fuel energy added in ExECU (99 percent combustion efficiency) = 17 GW; Fuel energy required to achieve 25.5 GW in boiler (80 percent efficiency) = 32 GW; Fuel consumption offset; electric power not generated by grid power plant: 6.5 GW at 35 percent efficiency: 18.5 GW; Net fuel consumption benefit: consumed – offsets: (23.2 +17) – (32+18.5) = -10.3 GW (20 percent reduction)

48 Klein, Joel. 2009. *Comparative Costs of California Central Station Electricity Generation Technologies,* California Energy Commission, CEC-200-2009-017-SD, p.3.

Figure 19: Schematic of the ExECU System



Exhaust control unit (ExEC) integrated with a prime mover and end-use equipment
Source: UC Irvine

Agreement Number: PIR-09-015 Contractor: University of California, Irvine
Project Cost: $666,285 Cofunding: $71,875 Project Term: 4/12/10 to 9/30/2013

Energy-Related Environmental Research

When pursuing improvements to California's energy system, new permitting and generation can sometimes be delayed by environmental protection regulations and processes. In a proactive effort to reduce these delays without negatively impacting California's environment—and without reducing the gains made by the state's comprehensive and important environmental laws—the Energy Commission invests in research to identify the best ways to pursue new energy projects in sensitive areas. The following projects represent some of the best examples of multidisciplinary policy problem solving at the state level. By researching and establishing the common impacts of renewable energy installations on their surrounding environment, future energy planning efforts can better avoid these impacts and avoid opposition from environmental interests.

The Project: Facilitating Renewable Energy Siting in the California Desert

Portfolio Status: Yielding Beneficial Results

The Issue: Utility-scale solar developments are crucial to achieving California's Renewables Portfolio Standard goal, which requires retail sellers of electricity to serve 33 percent of their load with renewable energy by 2020. However, such developments have large land requirements and can have negative impacts on fragile desert ecosystems and threatened species. To help address potential impacts of new renewable power plants and associated transmission lines, a science-driven Desert Renewable Energy Conservation Plan (DRECP) for the Mojave and Colorado Deserts of California is being prepared. To advance the DRECP, research is needed that would help minimize the biological impacts of solar projects within the plan area and streamline the permitting process. New information is needed to evaluate the impact of renewable energy technologies and designs and to provide planning tools to assist in

the siting, design, permitting, and mitigation of solar energy projects. For example, lack of detailed distribution and habitat information for the state-listed threatened Mohave ground squirrel was identified as a barrier to permitting. For the federally- and state-listed desert tortoise, there is little understanding of the ecology, habitat use, and resource needs of hatchling and juvenile desert tortoises that is needed to improve the success of mitigation actions.

The Research: To support the DRECP and aid environmental review and permitting, the Energy Commission continues to manage its desert research program. PIER initiated several desert projects in coordination with California Department of Fish and Game and the Energy Commission's Siting, Transmission, and Environmental Protection (STEP) Division. Two of these projects are highlighted.

Mohave Ground Squirrel Habitat Modeling to Guide Solar Development

This project provided new information on the distribution, potential habitat, and habitat corridors of the threatened Mohave ground squirrel over its entire geographic range within the DRECP plan area. The project constructed a potential habitat model by statistically relating previously collected observations of the species to environmental variables that represent biological or physical features. Combined with genetic data, this new potential habitat model was used to evaluate habitat corridors between Mohave ground squirrel population centers. Habitat corridors are pathways of natural habitat connecting neighboring natural areas that act as safe passages for wildlife. These habitat connections are the basis for minimizing population fragmentation while maximizing the long-term evolutionary potential of the Mohave ground squirrel, which will help ensure its survival. Habitat suitability was evaluated within the footprints of existing and proposed renewable energy developments. The databases used to develop the models and resulting maps of distribution and potential habitat are being made available for use by state and federal land management agencies, non-governmental organizations, private industry, and academia.

Improving Mitigation Success for Desert Tortoises at Renewable Energy Development Projects in the Mojave Desert

This project is rigorously evaluating the effectiveness of two innovative mitigation and recovery tools for juvenile desert tortoises to offset impacts of solar energy development. "Head-starting" maintains eggs and juveniles in semi-natural enclosures for a period of time to protect them from predators. "Jump-starting" provides rain supplementation intended to mimic natural rainfall patterns in non-drought years, a method suggested to nearly double the growth rate of hatchling tortoises. Survivorship and growth of head-started and jump-started tortoises at the Ivanpah Desert Tortoise Research Facility will be compared to free-ranging hatchlings released directly into Ivanpah Valley after hatching. If successful, this strategy may offset negative impacts of habitat loss by increasing survivorship during the critical first years of a tortoise's life. The project will determine the feasibility and effectiveness of head-start and jump-start desert tortoise rearing as a mitigation tool for use in desert tortoise recovery, especially as it relates to

ensuring long-term persistence of populations in protected areas to offset losses from energy development projects elsewhere in California deserts.

The Benefits: The goal of the desert research program is to remove barriers and delays in the siting of renewable energy in the desert. The desert research program benefits ratepayers by advancing the state's renewable energy goals and clean energy jobs, while helping to protect the state's fragile desert ecosystems. Streamlining the energy generation permitting process will help reduce energy costs and facilitate the timely and cost-effective integration of renewable energy to meet the state's required goals in this area. The projects above address critical data gaps that hinder biological impact assessment and mitigation and can lead to costly delays in environmental permitting. Results from this research program are useful to agencies, researchers, and developers in siting and conservation planning, impact analyses, and mitigation, resulting in fewer environmental impacts. Data on Mohave ground squirrel habitat suitability has already been used to develop preliminary conservation and energy alternatives for the DRECP and to assess impacts. Other data generated by the research project will be used to refine and expand the DRECP analysis.

Figure 20: Threatened Species and Renewable Energy

The Mohave Ground Squirrel is state-listed as a threatened species under the California Endangered Species Act.
Source: Desert Tortoise Preserve Committee

Figure 21: Threatened Species and Renewable Energy

A one-year old juvenile tortoise being weighed before being outfitted with a radio-transmitter and released to study habitat selection and survival in the wild to improve mitigation of impacts of solar energy development.

Source: Dr. Brian Todd, University of California, Davis

Mohave Ground Squirrel Habitat Modeling to Guide Solar Development: Agreement Number: 500-10-027 Contractor: U.S. Geological Survey Project Cost: $223,755 Project Term: January 2011 to January 2013

Improving Mitigation Success for Desert Tortoises at Renewable Energy Development Projects in the Mojave Desert: Agreement Number: 500-10-020 Contractor: University of California, Davis Project Cost: $238,310 Cofunding: $46,000 Project Term: November 2010 to March 2015

The Project: Assessing and Mitigating the Impacts of Energy Development on Birds and Bats

The Issue: As California moves towards achieving its renewable energy and greenhouse gas goals, avian and bat interactions with energy development pose a significant barrier. Wind energy is the major source of low-cost, clean energy within the state and represents over 21 percent of California's in-state renewable energy generation. About 1,585 MW of new wind generation was added in 2012 within the state. Permitting of such projects, however, is often delayed due to concerns over wind turbine induced bird and bat mortality.

Bird and bat interactions with transmission and distribution lines are also a major source of power outages within the state. California relies on a vast network of transmission and distribution lines to convey electricity from source to consumer. These power lines are a ubiquitous feature of the landscape; it is estimated that there are more than 6,000 miles of transmission lines in California's Central Valley alone. Avian interactions, either electrocutions or collisions with power lines, are estimated to cause more than 25 percent of all power outages. Such outages are costly; not only do they interrupt electric service, but they also damage equipment and cause avian fatalities, often of protected species. Estimates of the annual cost of such outages to California ratepayers range from $32 million to $317 million.

The Research: This research will help resolve areas of uncertainty regarding bird and bat interactions with wind turbines and transmission and distribution lines. For wind turbines, this includes linking pre-permitting data on bird and bat use with operational fatalities, and validating techniques to avoid, minimize, and mitigate bird and bat fatalities, including innovative wind turbine designs and tools for assessing avian and bat behaviors around wind turbines.

For avian interactions with distribution and transmission lines, there is a need for research to identify lines and poles with the highest risk for bird electrocutions and collisions to improve transmission line and distribution line siting and limit mitigation (retrofit) costs by focusing on high priority areas. The first project is an on-going effort that promises benefits from a highly efficient wind turbine that substantially reduces the risks of bird and bat collisions. The results from the following two studies are already being used.

Avian interactions, either electrocutions or collisions with transmission lines, are estimated to cause more than 25 percent of all power outages.

The New Mixer Ejector Wind Turbine: A Hope for Birds and Wind Power

Portfolio Status: Ongoing Research with Significant Potential

A major source of avian fatalities from wind turbines is the failure of birds to recognize the thin, spinning turbine blades of conventional horizontal axis turbines during flight. Therefore, development of an alternative wind turbine design may significantly reduce avian collisions. This project is assessing avian interactions of a new, shrouded wind turbine design using mixer ejector wind turbine technology. This turbine design consists of two concentric covers, or shrouds, that draw more air into the turbine face than existing wind turbines of the same rotor diameter. This provides greater energy output per swept area and, on a per kilowatt basis, allows a smaller swept area and lower overall height. These turbine characteristics not only offer an opportunity to replace other, lower efficiency, high collision-risk turbines and use less productive wind areas, but perhaps to do so with fewer bat and avian collisions.

The study will evaluate whether the shrouded design will reduce bird collision fatalities because the shroud will prevent birds from flying into the most hazardous angles of entry in the blade-swept area. The shroud will also likely increase visibility of the rotor plane, thereby offsetting the effects of motion smear, which is the appearance of rotating blades as a transparent smear or blur that birds incorrectly interpret as a safe area to fly through. This project will test this wind turbine model in the Altamont Wind Resource Area in eastern Alameda County by conducting day and night surveys to compare not only avian fatality rates between turbine design but also flight patterns and avoidance behaviors.

Novel Survey Methods for Bird and Bat Movement and Mortality at the Montezuma Hills Wind Resource Area

Portfolio Status: Yielding Beneficial Results

Birds and bats are important factors in wind-energy siting and permitting. A major challenge to assessing a site's potential for bat and avian collisions is determining nighttime use of the area. Many birds migrate at night; yet conducting nocturnal surveys is difficult, time consuming, and costly. The adopted avian guidelines identified nocturnal surveying methods as an important research need. This project evaluated the efficiency of using radar, night vision, and acoustic monitoring technologies to document night-time bird and bat activity at a wind farm during two migration seasons. The study sought to establish a relationship between estimated abundance for birds and bats flying at altitudes falling within the rotor-swept areas of turbines or higher and bird and bat fatality estimates derived from intensive carcass surveys. Results from the study show that overall radar-identified passage rates and fatality in the study area were not correlated, but that there was a positive correlation between fatality rates and passage activity in the high-risk, blade-swept zone, suggesting that altitude-specific radar monitoring can be useful for monitoring fatality risk for birds in this wind resource area. Acoustic monitoring did not produce enough data to provide useful information about movements of bats and nocturnally active birds through the study area or to compare acoustic surveying techniques with the other sampling methods assessed in this study. Finally, using night vision was successful in monitoring bird movements in a smaller area than radar and provided good information on bat and bird behavior in the immediate vicinity of the wind turbines.

Efficiently Reducing Power Outages from Avian Interactions

Portfolio Status: Yielding Beneficial Results

Avian contact with overhead electric equipment can result in bird electrocution, equipment damage, and power outages. Such specific interactions include collisions and undesired perching or nesting that can harm system reliability by causing outages or equipment damage and fires. Avian electrocutions can also violate federal and state laws. To identify high risk structures for retrofitting to reduce the risk of electrocution, this project reviewed Southern California Edison's (SCE) avian interaction and outage records. This study also assessed the effectiveness of retrofitting an existing SCE transmission line with conductor covers to reduce avian electrocutions and resulting outages. Finally, the project developed a model, based upon SCE data, to predict high-risk structures from avian interactions. The study found that retrofitting the transmission lines reduced bird-related outages by as much as 74 to 82 percent and that the model successfully predicted problem poles based on data from only a few variables. The study results show that retrofitting transmission and distribution lines can significantly reduce power outages resulting from avian interactions. By using the model, SCE will be able to focus such efforts on those poles and lines that are high risk to avian collisions and electrocutions.

The Benefits: The goal of the research on avian and bat interactions with energy resources and facilities is to reduce fatalities from collisions and electrocutions and make permitting of energy facilities in California easier. The results from these and other projects being conducted by the program are showing ways to facilitate the permitting process through improving methods and tools to assess impacts as well as assessing innovative turbine designs that may reduce such collisions. The Novel Survey Techniques study described above is already being used by the Alameda County Scientific Review Committee for the Altamont Wind Resource Area to assess proposed and on-going wind energy projects.

By conducting research to reduce avian interactions with distribution and transmission lines, this program is helping to reduce power outages and the costs such outages entail. These studies show that there are tools available to reduce such interactions and to identify high-risk poles and lines where retrofitting is needed. SCE is using the results from the Power Outage Report to significantly reduce wildlife induced outages on other lines within their service territory.

Results from this research program are also useful to agencies, researchers, and developers in siting and conservation planning, impact analyses, and mitigation, resulting in fewer environmental impacts.

Figure 22: Red-Tailed Hawk and Wind Turbines

Source: http://baynature.org/articles/raptors-and-windmills-in-an-era-of-climate-action/

Figure 23: Computer Rendering of the Shrouded Wind Turbine

Photo credit: FloDesign, Inc.

Efficiently Reducing Power Outages from Avian Interactions: Agreement Number: PIR-08-026 Contractor: EDM International, Inc. Project Cost: $165,516 Cofunding: $37,000 Project Term: June 2009 to June 2013

Novel Survey Methods for Bird and Bat Movement and Mortality at the Montezuma Hills Wind Resource Area: Agreement Number: PIR-08-027 Contractor: H.T. Harvey and Associates Project Cost: $732,411 Project Term: June 2009 to June 2013

The New Mixer Ejector Wind Turbine: A Hope for Birds and Wind Power: Agreement Number: PIR-11-022 Contractor: Shawn Smallwood Project Cost: $716,596 Cofunding: $174,498 Project Term: June 2012 to March 2015

The Project: Potential Scenarios for California's Energy Future

Portfolio Status: Ongoing Research with Significant Potential

The Issue: California's energy system must change drastically over the next few decades in response to policy goals to reduce greenhouse gas emissions and increase the level of renewables in the electricity mix. Given the fast pace of transformation of California's energy system, non-traditional power plant project proposals (for example, offshore wind) should be expected. To ensure that reducing greenhouse gas emissions from the electricity system does not result in unintended environmental impacts, there is an urgent need to anticipate the potential evolution of the energy system, begin investigating the environmental implications of these potential scenarios, and, as needed, to collect environmental baseline data and develop improved methods to track environmental changes.

The Research: The research team is enhancing a newly developed model of the electricity system known as SWITCH (a loose acronym for Solar, Wind, Hydro and Conventional generation and Transmission Investment model) that is able to generate high-resolution simulations of intermittent renewable energy resource demands. The model's objective is to minimize the cost of meeting projected electricity demand with generation, storage, and transmission from present day until 2050, taking into consideration capacity, environmental, operational, and policy constraints. Other parts of the energy system, like residential energy

demand, will be accounted for using an enhanced version of the Long-range Energy Alternatives Planning System (LEAP) model.

The researchers are simulating several potential energy scenarios under different policy options, like carbon prices or cap-and-trade programs, to advise long-term energy planning. Work so far has examined the multiple energy pathways available for meeting California's 2050 greenhouse gas targets.

Under a second phase of the project, researchers will conduct high-level analysis of the environmental implications of selected energy pathways (for example, the amount of water needed for cooling and the amount of land affected).

The Benefits: Unlike other power system models, SWITCH can address both day-to-day operations and dispatch and long-term capacity expansion. It is able to handle a large volume of data covering all aspects of the electricity system and subject them to reliability, operational, and resource availability constraints. The model's unique combination of spatial and temporal detail enables researchers to design realistic power systems and plan capacity expansion to meet multiple policy goals and carbon emission reduction targets. Additionally, the open source format of the model will allow widespread use of the model.

The energy scenarios resulting from this effort will provide insight on strategies that could be used to achieve California's long-term greenhouse gas emissions reduction goals for 2050 as well as midterm goals such as 2030 at minimum cost. By anticipating the changes to California's energy system needed to meet those goals, this project will facilitate planning and guide investments in the energy system. It will also help California decision makers anticipate negative environmental impacts of these changes and develop mitigation strategies in advance.

Agreement Number: 500-10-047 Contractor: UC Berkeley Project Cost: $900,000
Project Term: July 2011 to September 2013

Energy Infrastructure Research

Why Today's Energy Infrastructure Needs Innovation

Since Thomas Edison designed the first electricity station in 1880, maintaining reliable electricity systems has become amazingly complex. The electric grid must connect generators of all sizes and types and transmit electricity of varying voltage across sometimes vast distances to diverse users, from manufacturing plants to mountain cabins. The grid is physically massive and fixed but must accommodate demand that fluctuates from one instant to the next. Electricity demand generally peaks on weekday afternoons during a summer heat wave, but historically the grid has needed the physical capacity to meet that demand year-round; expensive "peaker plants" that are used only during peak times must be built and maintained. These are merely a few of the existing challenges that faced yesterday's grid; entering a low-carbon, high-tech future requires the grid's very nature to evolve.

The electric grid was once a one-way system, with centralized plants using cheap, abundant fossil fuels to send power out to users. Now, advancements in energy efficiency, renewable generation, and other energy areas depend on grid improvements. For example, increasing amounts of rooftop solar panels, other distributed renewable energy sources, and plug-in electric vehicles require the grid to flexibly manage power flowing both ways. Demand response technologies that prompt users to use less energy during peak periods make the grid more reliable, but they also require two-way communication between generators and users. Renewable sources like solar and wind have variable output, so the grid must also now be able to store and use that energy on demand: otherwise, low output periods (like cloudy, windless days) could cause grid instability or blackouts. California's economy, safety, and environment depend upon these and other transformations of the electric grid.

The Infrastructure Vision for California's Future:

California's electricity future by 2030 and beyond will be supported by a flexible and robust distribution and transmission infrastructure*: power will be managed by advanced technologies, more generation will be distributed, renewable power will be well-integrated, and modern improvements will reduce environmental impacts.*

The Energy Commission funds energy infrastructure research in multiple areas to support these goals. Research focuses on demonstrating key products and elements of the energy infrastructure, as well as the cost-effective integration of all new and emerging technologies and solutions that will build a smart energy infrastructure for California.

Research completed in the Energy Infrastructure Program involves a wider spectrum of research priorities and challenges than the previous two research areas. The research is focused on demonstrating not only key products and elements of the energy infrastructure, but the successful and cost-effective integration of all these new and emerging technologies and solutions.

The Project: Demonstrating the Benefits of a Microgrid that Integrates Renewable Energy Systems

Portfolio Status: Yielding Beneficial Results

The Issue: A microgrid is a smaller-scale version of the traditional power grid. It consists of distributed energy resources, such as energy storage, along with renewable or other generation, all integrated together as a single power generation source that can operate independently, but still remain tied to the main utility power grid. Starting with a $1 million PIER grant in 2008 and leveraging more than $4.2 million in support from other state, federal, and private sources, the University of California, San Diego (UCSD) integrated a diverse set of distributed energy technologies into an effective microgrid.

As one of the largest microgrids in California and the most diverse in terms of energy resources, incorporating solar PV, biogas, combined heat and power, fuel cells, and electric vehicles (EVs), UCSD's microgrid is one of the best examples of an electricity network that provides local control yet is interconnected with the larger electricity grid. The microgrid self-generates 92 percent of the campus' annual electricity load and 95 percent of its heating and cooling load.

The Research: This research will show how renewable generation, energy storage, and electric vehicle charging can be integrated to work together in a microgrid to provide grid support and improve overall grid reliability. The latest additions to the microgrid will be additional distributed energy storage systems and EV chargers. This project will analyze and enhance the performance of all the campus energy resources through the microgrid master controller. After this project is completed, UCSD will have the largest, most diversified portfolio of electricity energy storage and EV charging stations located on any university campus in the world.

The Benefits: This demonstration of a smart grid ecosystem that increases the use of renewable resources and improves the energy security of the local community will benefit California ratepayers by reducing peak energy demand and improving electric reliability. Results will inform microgrid implementation for multi-building facilities with high levels of renewable generation and electric vehicles, such as the United States military.

The ability of UCSD's microgrid to optimally manage multiple renewable resources enables fast, efficient EV charging. Using grid-connected photovoltaics with distributed energy storage to power the EV chargers helps reduce carbon emissions. Sixteen of the new EV charging outlets on campus will be available to the public.

The microgrid can also provide time-critical services, such as demand response, that reduce system pressures on San Diego Gas & Electric's utility grid during peak energy demand periods. In 2012, UCSD provided the California ISO with remote monitoring capabilities to view its microgrid operations at any level. This information helps grid operators understand how UCSD's microgrid can provide grid support during critical energy events. This research is establishing an important breadth of operational knowledge about how to manage a variety of different energy resources as an integrated system, expand the amount of renewable energy in a system, as well as accept and implement new and creative energy efficiency measures.

The Energy Commission began funding the UCSD microgrid with a $1 million grant in 2008 that UCSD has leveraged, with over $4 million in support from other state, federal, and private sources. By helping establish the campus' research and demonstration of its microgrid, the Energy Commission helped bring new jobs and advanced technologies to California. The system's EV chargers are five years ahead of standards: their intelligent, connected, controllable charging meets all 2017 requirements for communication between EVs and charging equipment. RWE Effizienz GmBH, a subsidiary of a German utility, which is the maker of the charging equipment, selected California-based AeroVironment, Inc., as its designated assembler and distributor of RWE direct current fast chargers and alternating current intelligent chargers for the U.S. and Canada markets. RWE's RWE is currently the only charger manufacturer with commercially available chargers certified to meet these future standards.

Figure 26: UCSD Microgrid Tour with the U.S. Navy

California Energy Commission Chair Robert Weisenmiller and former United States Assistant Secretary of the Navy Jackalyne Pfannenstiel tour the UCSD microgrid. The UCSD campus has a similar energy footprint to a military base.

Photo Credit: University of California, San Diego

Agreement Number: 500-10-043 Contractor: The Regents of the University of California, San Diego
Project Cost: $2,994,298 Co-funding: $1,714,672 Project Term: June 20, 2011-March 31, 2015

Innovation Profile

Synchrophasors: The Technological "Canary on the Power Line"

Although electricity seems a simple part of everyday life –lights go on at the flip of a switch, power flows instantly from an outlet to charge a laptop—the actual process of producing and delivering that electricity is incredibly complex. Electricity frequencies vary continuously, as does demand, and system operators must therefore adjust their management of the grid continuously while staying within the built infrastructure's safe limits. Modern changes, like increasing levels of distributed energy and changes to the way Californians use energy, make managing the grid even more challenging by intensifying variability in both supply and demand. The system has historically lacked advanced technology to address this issue.

Just as coal miners once used canaries to alert them to toxic air, California's grid needed a highly sensitive early-warning system to meet modern challenges. The Energy Commission's PIER program developed a new technology that gives operators unprecedented information about problems in real time, and helps them avoid and respond to these problems. These technologies, called synchrophasors, measure electrical waves at multiple locations on the grid simultaneously.

California's Independent System Operator (ISO) now uses these essential technologies, and the ISO Director called synchrophasors "the most significant improvement in control room technology" in his career. Before synchrophasors, a single downed transmission line could cause blackouts across multiple states; now, operators have high-resolution data about instantaneous frequency changes that allows them to respond more quickly to problems anywhere on the system.

In 2012, PIER synchrophasor research built upon past successes. Synchrophasors are now commercially available and are used across the Western Electricity Coordinating Council. California's ISO is sharing its synchrophasor data with operators in other states, as well as integrating data with the other tools that it uses to operate the grid. As a result of these improvements, the ISO sees California electric grid changes more clearly, compares data more effectively with interconnected systems outside the state, and is better equipped to make coordinated responses to any event or problem on the grid.

Improving grid management technologies makes the system safer and more reliable, which benefits ratepayers and the economy. By 2020, synchrophasors and related applications will save Californians an estimated $210 million to $360 million in avoided outage costs due to increased reliability, and provide $90 million per year in economic benefits.

What are synchrophasors, and what do they do?

- *Synchrophasors are measurement devices that provide highly detailed, highly accurate information. This allows grid operators to better match varying generation levels with demand.*
- *They identify and pinpoint disruptions on the electric grid.*
- *They monitor energy power flows across transmission pathways.*

What benefits do they provide?

- *Greater grid reliability, lowered electricity costs, and increased safety due to lower risk of blackouts and grid disruptions*
- *Increased integration of renewable energy into the grid and associated energy savings and environmental benefits*
- *Increased energy efficiency*

Energy Storage and Infrastructure Flexibility

In California's low-carbon, flexible-grid future, energy storage will be used for multiple purposes. Energy storage technologies can be used to store energy in periods of low demand and high production; for example, day-to-night atmospheric pressure changes often cause higher winds in a given area to occur at night, causing wind energy generation to be highest at night when electricity demand is low. Storage is also used to regulate the output power of renewable generation sources (the output of a wind turbine is hardly a smooth curve, with various spikes and dips corresponding to each gust) and this "smoothing" must occur for renewable energy to be integrated more easily into the overall grid. Using energy storage to smooth renewable output prevents GHG emissions from conventional fossil fuel generators that have predominantly been used for this purpose because storage and battery technologies were not advanced enough. For the smoothing to be accomplished by emerging energy storage technologies, advances are needed to make them cost competitive with conventional generation. The issue of present and future value is one that is elusive for these emerging storage technologies. Through funding research and demonstrations of energy storage technologies, the Energy Commission is helping provide real-world data to innovators and grid operators. This information will help define the roles of energy storage in the electricity system.

The Project: Adding California Sunshine to the Grid Using Advanced Batteries

Portfolio Status: Ongoing Research with Significant Potential

The Issue: As discussed in Chapter 1 of this report, energy storage technologies have the potential to increase the reliability of California's energy supply and improve operators' ability to dispatch energy sources. There is a growing need for energy storage in California's electricity grid to integrate variable renewable energy, provide ancillary services, manage peak demand, and relieve transmission and distribution congestion. Building a portfolio of energy storage options will address these system challenges.

The Research: The sodium-sulfur battery energy storage system is one of the most advanced battery storage technologies on the market, with more than six hours of energy storage capacity, high efficiency of about 80 percent, and a long life span of 15 years. PG&E installed a 2 megawatt (MW), 14 megawatt-hour (MWh) sodium-sulfur battery system at its Vaca-Dixon substation and will install a 4 MW, 28 MWh system at the end of a distribution line connected to the Hitachi Global Storage Solutions facility in San Jose.

PG&E's Vaca-Dixon substation is close to the Vaca-Dixon solar plant, which is capable of generating about 2 MW of peak power. The installed 2 MW battery installed will test the use of energy storage at the substation level to manage this intermittent resource and will be tested for its ability to provide other grid services, depending on customer demand. PG&E views the Vaca-Dixon installation as its energy storage test bed, which will be used to test and evaluate many energy storage use scenarios, helping to define the roles energy storage may fulfill within the overall grid.

The battery installation at the Hitachi facility will serve to enhance power reliability for customers on the distribution line by mitigating fluctuations. Multiple hours of backup power provided by the battery system will reduce emissions from the facility's diesel backup generator normally used during power outages. The 4 MW battery will also have the capacity to fully power the entire facility in the event of a grid outage, helping the facility to reduce the risk of harmful, expensive electricity service disruptions.

The Benefits: Energy storage can provide multiple benefits to California's electric ratepayers by helping to stabilize the grid, improving service reliability, and reducing financial losses associated with power outages. Storage can offset the need to purchase and install new generation, as well as reduce the use of highly polluting peaking power plants during periods of high demand. When compared to the slower response rates of traditionally dispatched conventional fossil fuel-powered plants, the fast ramp rates of sodium-sulfur batteries are particularly suited to support the integration of large amounts of variable renewable energy, helping to meet California's visionary renewable energy goals. This project is poised to provide future benefits in a crucial energy research area. Currently there is a lack of real world data that demonstrates the abilities of energy storage to serve multiple grid functions discussed above. Data gained through this installation, as well as the one currently under construction at the Hitachi Global Storage Technologies facility in San Jose, will help to inform not only PG&E, but organizations such as the CPUC, California ISO, the Electric Power Research Institute, and other energy storage investors and innovators.

Figure 27: Testing Sodium-Sulfur Batteries on California's Grid

2 MW / 14MWh Sodium Sulfur Battery installation at PG&E's Vaca-Dixon Substation
Source: Pacific Gas and Electric

Agreement Number: 500-09-027 Contractor: Pacific Gas and Electric
Project Cost: $3,300,000 Cofunding: $8,000,000 Project Term: June 2012 to June 2014

Energy Innovations Small Grant Program: Seeding Innovation and Market Success

In addition to large-scale demonstration projects, the PIER Program manages the Energy Innovations Small Grant (EISG) Program that awards grants of up to $95,000 to test and evaluate new and innovative energy concepts and ideas. Three of the following EISG projects achieved notable industry and market success in 2012; the fourth is an exceptional example of a just-started project that is poised for potential industry success as well. These cases demonstrate the enormous possibility intrinsic in many of the smaller strategic investments made in the energy sector.

The Project: Primus Power's Flow Batteries, From Conception to Market

Portfolio Status: Yielding Beneficial Results

The Issue: California's Renewables Portfolio Standard is increasingly being met with intermittent renewable resources such as wind and solar. Intermittent renewable resources, coupled with California's economic structure demanding higher quality power, have focused attention on the need for highly reliable backup power and energy storage options. Currently, energy storage options are expensive, inefficient, or focused on particular storage periods (for example, subcycle, diurnal, seasonal). More importantly, today's substation backup power is typically met with lead-acid batteries that pose safety and disposal risks and short-storage back-up capability of about four to six hours.

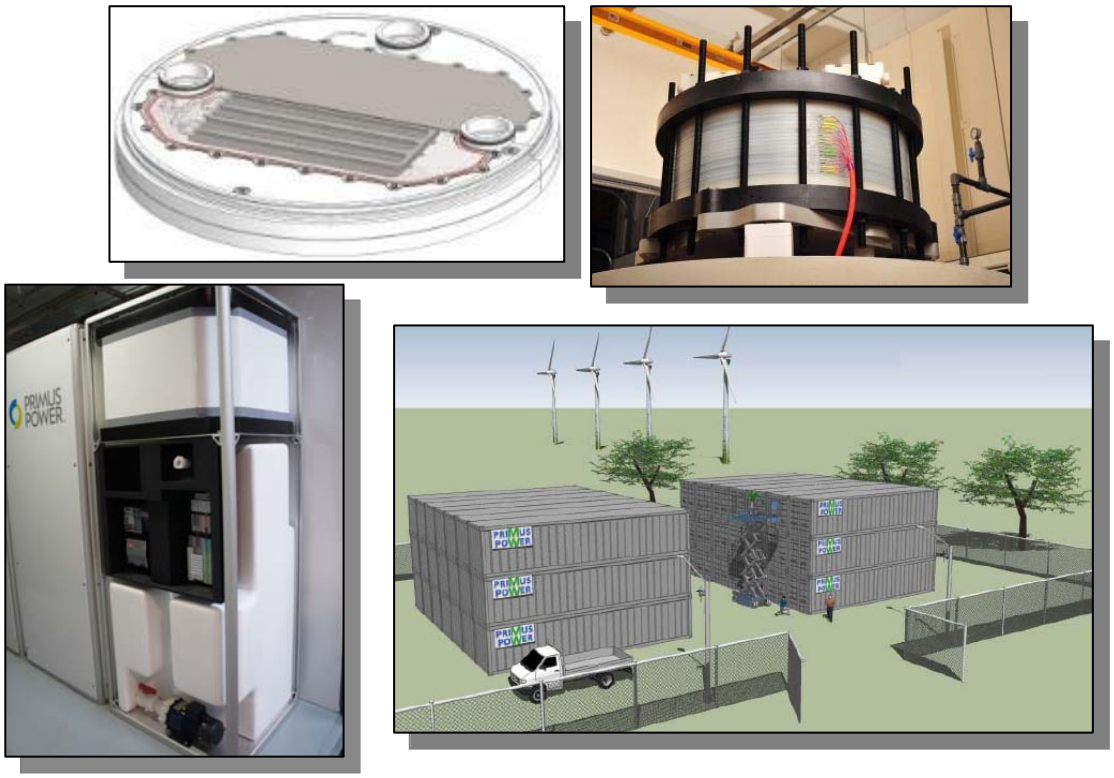
The Research: This project sought to demonstrate the technical feasibility of an inexpensive, highly efficient, and reliable flow battery for substation backup power. As increasingly large amounts of intermittent power resources are connected to the electric grid, the need for energy storage and immediate response backup increases, especially at the substation level. This project validated the feasibility of a flow battery design for this purpose. The key components of the prototype evaluation were system integrity, manufacturability, and design safety. The actual prototype performance exceeded pre-established energy density goals. Achieving greater energy densities is a critical advancement area in energy storage research.

The Benefits: The primary public benefit of this technology to California ratepayers would be the increased reliability of the California electric system. Reliability benefits would accrue from the reduced impact of power outages, improved power security, and shorter response times. During power outages, the technology could extend substation control power for up to four days rather than a few hours. This could improve response times for re-energizing the grid and restoring customer power at a lower cost than the traditional power purchases. The use of naturally occurring, low-toxicity electrolytes will provide a system with increased safety and increase ease of disposal.

Following the initial funding through a $95,000 EISG award in 2006, Primus Power has made significant technical progress, hired 25 highly skilled professionals, and attracted more than $30 million in grants from the Department of Energy and investments from top tier venture capitalists. Primus Power is part of a $47 million project to install a 28 MW grid storage system

in Northern California, including $14 million U.S. DOE and $1 million PIER funding. For an initial investment of $95,000 in a research concept, the Energy Commission supported the progress of flow batteries from idea to product.

Figure 28: Primus Power's Battery, From Conception to Market



Top left: Primus Power's initial proposed design. Top right: The alpha scale test model Bottom left: The beta EnergyCell design Bottom right: A rendering of the planned renewable energy-Primus Power storage system in the Modesto Irrigation District.

Source: California Energy Commission

Agreement Number: 500-98-014 -4 Contractor: Primus Power

Project Cost: $95,000 Cofunding: $73,500

Project Term: December 2006 – February 2009

The Project: Seeding Success for Wireless Lighting Control Systems

Portfolio Status: Yielding Beneficial Results

The Issue: Interior lighting represents a significant portion of commercial building electricity use in California. In many buildings, lights are often on when unneeded, such as in areas near windows during strong daylight hours, in periods of low occupancy, or in rarely-used alcoves or storage areas in an open floor plan. There is little opportunity to reduce usage at scale in these areas due to inadequate controls for this type of selective lighting regulation, especially in older buildings where re-wiring and control equipment can be expensive.

A lower-cost solution using wireless control communications could allow flexible lighting control to be retrofitted in many buildings. This technology could allow occupants to adjust their local lighting and make it possible for building managers to control large banks of lighting in individual groups, rather than as a whole.

The Research: This project sought to prove the feasibility of an easy-to-install lighting control system. The developed system used low-power wireless transceivers to communicate between wireless switches on walls and wireless relay devices that fit into a standard fluorescent fixture. The system was installed in multiple pilot and demonstration locations in California, proving electricity savings and a short payback period.

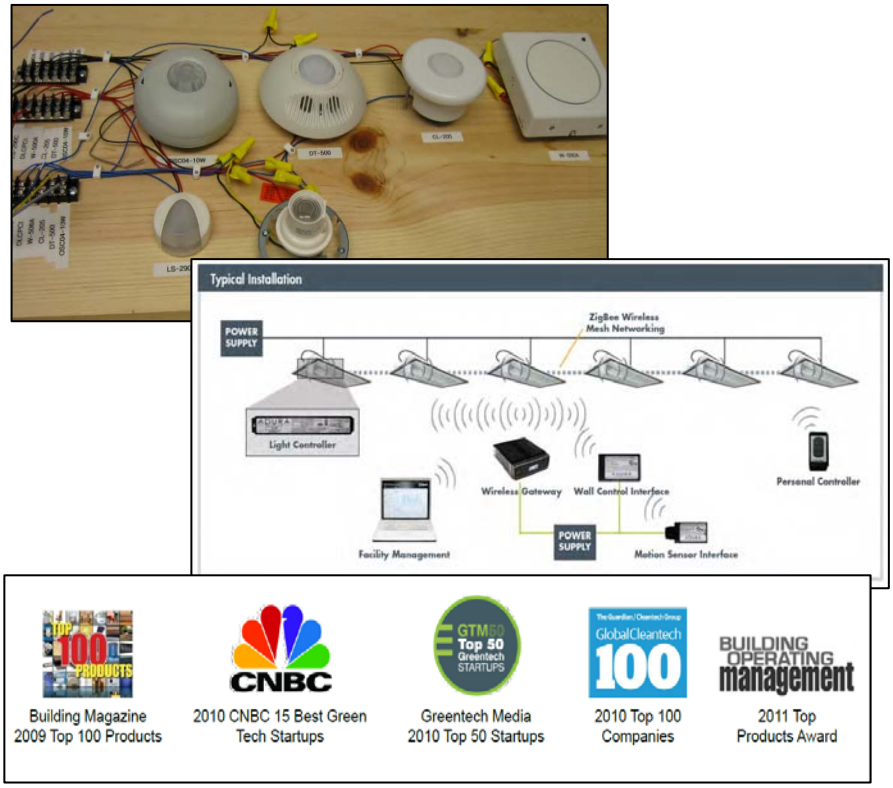
The Benefits: The primary benefit to the ratepayer from this research is increased affordability of electricity in California. The results in this project suggest that at commercial scale, this technology can yield substantial savings in lighting energy in many commercial buildings. Actual savings would vary by building type, purpose, age, and retrofit potential. As an example, retrofitting 25 percent[49] of small and large offices, schools, and colleges in California and achieving an average 50 percent reduction in lighting energy would yield a total lighting energy savings of roughly 800 GWh per year. With roughly 10 percent of California's peak demand attributed to interior lighting, the technology should also provide peak reduction benefits in many installations.

This project has also brought significant levels of match funding to the state. Adura Technologies secured about $25 million in funding, including $8.5 million in 2012. The company currently has several products based on EISG technology commercially available. In January 2013, Adura Technologies was purchased by Acuity Brands, Inc., a larger lighting efficiency and controls company.

The remarkable progress made by Adura Technologies after it secured initial EISG support demonstrates the results PIER seeks to achieve for all its efforts: testing and demonstration, verification, followed by market investment and active use in the end-use sector.

49 Continued rebates for lighting retrofits would likely be required to achieve this penetration rate.

Figure 29: Wireless Lighting Technologies' Progress, From Testing Stage to Market Success



After demonstrating and testing the wireless control systems, Adura developed and implemented a fully integrated system. The success and savings of the system garnered industry and market success, culminating in the early 2013 acquisition of the company by a larger corporation.

Source: California Energy Commission

Agreement Number: 500-98-014-4

Contractor: UC Berkeley/Adura Technologies/Charlie Huizenga

Project Cost: $74,195 Cofunding: $6,353 Project Term: January 2005 – December 2007

The Project: Reducing the Cost of Distributed Generation through Grid-tied Inverters

Portfolio Status: Yielding Beneficial Results

The Issue: Distributed generation (DG) can reduce local facility electricity costs by reducing peak energy use and providing cogeneration services. It can also reduce delivery requirements on the larger electricity supply system, while improving power quality factors. Many end uses that may benefit from DG have very high power quality requirements or impose power quality concerns for the grid. For example, variable-speed drives, battery chargers, and other energy-intensive technologies that are prevalent in office buildings and industrial settings often produce distortions in electrical currents called harmonics. These applications need very high quality power. But many renewable energy generation technologies require an inverter to connect to the grid, which can be a significant percentage of the system's installed costs. Often when installing DG, especially using photovoltaic systems or fuel cells, users must purchase both an inverter and power quality filter. At the time this project was started, no product was

offered commercially that performed both functions. A single device performing both functions could lower the overall cost of installing distributed generation.

The Research: This project demonstrated a one-cycle control, 5-kW, three-phase power converter that functioned both as a grid-tied inverter and as a power quality filter to suppress harmonics and improve power factor. The prototype delivered up to five KW of grid-tied power, reduced harmonics from 27 percent to 5 percent, and improved the system power factor (the ratio of real delivered power to apparent power) from 0.7 to 1.0. The developed device performed two functions and therefore delivered potential cost savings for many DG applications. Combining grid-tied inverters with power quality filters may lead to decreased capital, installation, maintenance, and electricity costs compared to individual systems.

In December 2012, the project contractor, One- Cycle Control, Inc., shipped its first voltage stabilization node to a utility customer. The unit delivers grid stabilization services to enable high penetration of renewables. The one-cycle control, reactive-power system has a footprint 7 to 10 times smaller than previous technologies and delivers greater dynamic capabilities. Because it uses only one cycle, the system is simpler to build and maintain, and it can be added to existing transformers.

The Benefits: The primary benefit to the ratepayer from this research is increased affordability of electricity in California. Reduced environmental impacts of the California electricity supply system are a secondary benefit. DG applications can provide cost savings to users. To the extent that this multi-function device lowers the cost even further (compared to multiple component usage), expanded or more rapid deployment of DG may occur.

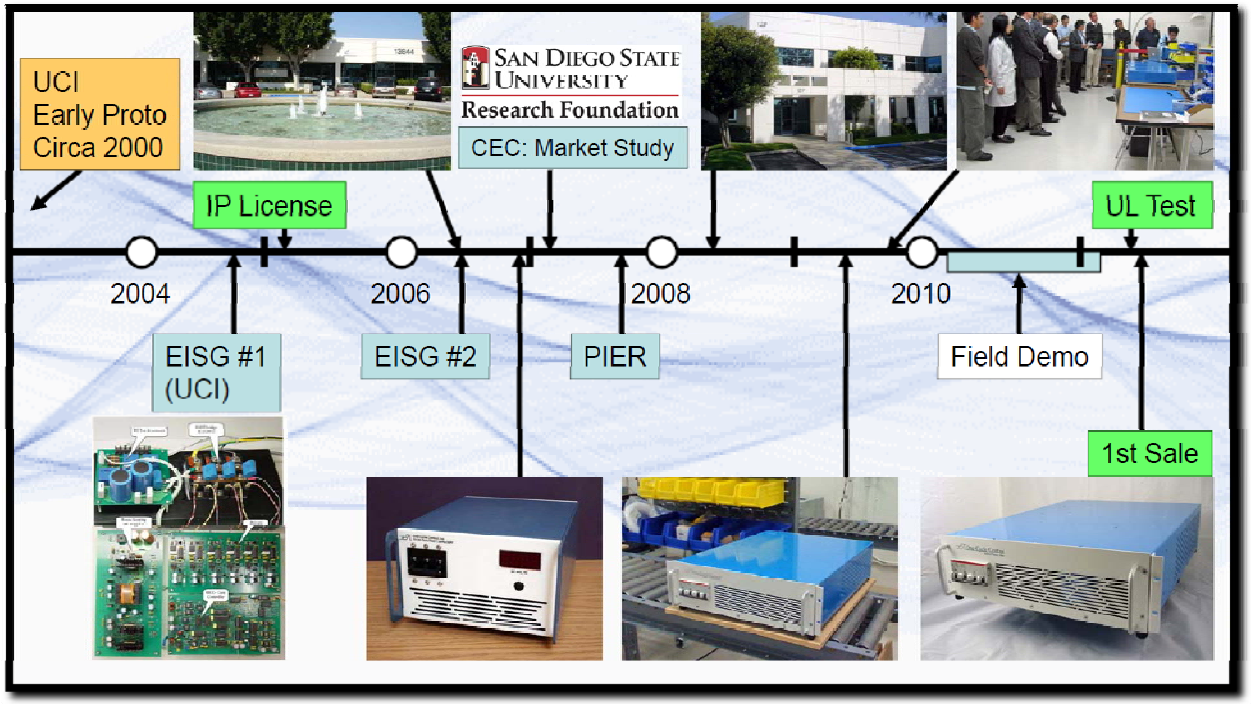
Energy Research Terms:

Energy-intensive technologies often produce distortions in electrical currents called ***harmonics****.*

A 1 percent decrease in annual statewide supply-side grid generation (a reduction of 2,380 GWh) could be achieved if 12 percent of industry customers install 100 kW of on-site generation or five percent of commercial customers install 10 kW of on-site generation (if both, then a two percent reduction might be achieved.)[50] The market penetration levels of distributed generation could be increased if the costs of control and interconnect electronics are significantly reduced. This project was aimed at reducing the cost of the inverter circuit and the power quality circuit. Given the economy of scale for the cost of the combined electronics, market penetration would be higher in larger industrial applications.

50 *Electricity Outlook: Summer 2005 and Beyond*, 2/22/05, www.energy.ca.gov/electricity

Figure 30: Grid-tied Inverters, from EISG to Market



One-Cycle Control's grid-tied inverters tested first by PIER's EISG program subsequently advanced to the development and demonstration phases, were tested by safety organization UL (Underwriters Laboratories) and have entered the market.

Source: One-Cycle Control

Agreement Number: 500-98-014-5 Contractor: One-Cycle Control, Inc.

Project Cost: $75,000 Cofunding: $41,340 Project Term: June 2006 – October 2007

The Project: Generating Efficient Power from Solar Systems on Cloudy Days - Hybrid, Flameless Solar Receivers

Portfolio Status: Ongoing Research with Significant Potential

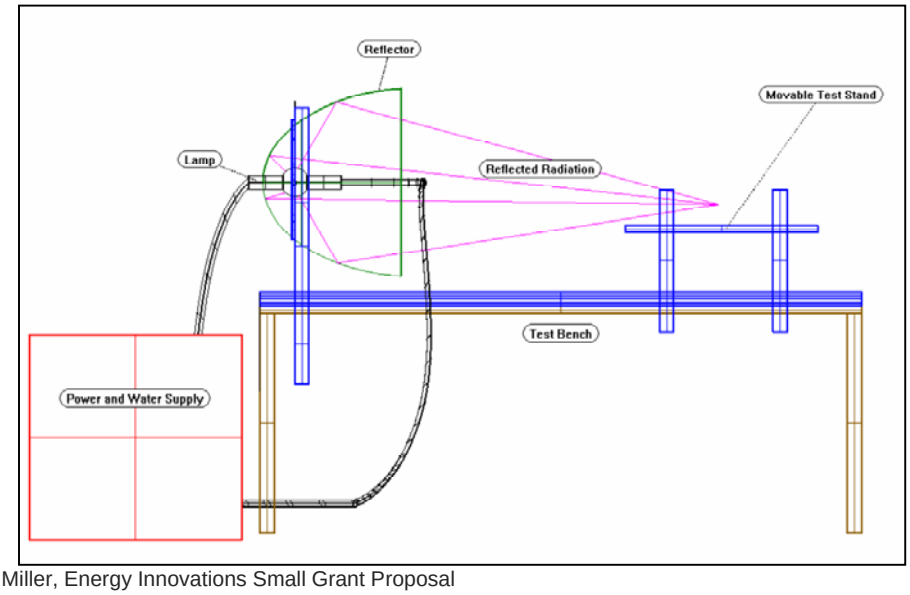
The Issue: In California, the deployment of many solar thermal plants is often hindered by concerns over water usage. Because the plants generate electricity from steam produced after solar energy has heated a fluid (usually oil or water), they can use significant amounts of fluid. To meet state renewable energy goals and increase the level of solar thermal energy in California, solar power plants must become more efficient to reduce water consumption and minimize costs. This is particularly true in areas prime for solar thermal plants like the desert.

The Research: This project seeks to determine the feasibility of employing flameless combustion within an air-cooled, solar central receiver to achieve hybrid operation for periods of reduced solar input. The receiver will be designed to oxidize natural gas as a supplemental heat source during cloudy days and other periods of reduced solar energy. This will increase the temperature of the working fluid and ensure steady state operation.

The Benefits: Solar-powered gas turbines can potentially reduce power plant costs through increased energy production, reduced operation and maintenance costs, and increased efficiency. These cost savings can then be directly translated into lower energy costs to consumers. After developing this concept with EISG funding over 2011 and 2012, the contractor received a $3.9 million grant in October 2012 from the U.S. Department of Energy to build and test a full-scale prototype of the EISG-developed technology.

This project has thus shown promising potential for replicating the success of the other EISG projects profiled in this section; it demonstrates how the crucial early support made by PIER allows new ideas to become poised to provide significant future savings to California energy users.

Figure 31: Initial Rendering of the Receiver Concept



Source: Fletcher Miller, Energy Innovations Small Grant Proposal

Agreement Number: 500-98-014 -7 Contractor: San Diego State University/Fletcher Miller
Project Cost: $94,940 Project Term: March 2011 – January 2012

Creating Jobs in California

The PIER Program makes targeted investments in innovative, energy-related RD&D projects, attracts and grows businesses, and creates jobs. The Energy Innovations Small Grants (EISG) program in particular is a powerful engine for private investment and economic activity. Energy Innovations Small Grants totaling $34 million over 13 years from 2000 through 2012 have led to more than $1.8 billion in follow-on investment, including $1.65 billion of private, non-utility follow-on investment. That is 50 times the $34 million the Energy Commission invested in this small-grants program.

Jobs Supported in 2012

An estimated 5,360 Californians were gaining innovation skills and experience working part or full time in 2012 on PIER-funded projects related to electricity use or generation. These Californians are working the full-time equivalent of 2,800 jobs and creating an additional 4,500 full-time-equivalent jobs as employers and employees purchase goods and services. In total, 2012 PIER projects are sustaining 7,300 full-time jobs.[51] This contributes to the climate of innovation in California because local research has local spillover. Creating innovation in a region has been shown to increase the probability of further innovation in that region six-fold.[52]

Long-term Projections for 2012 Projects

Energy Commission staff collected job-creation projections from contractors with available data and active projects in 2012. Contractors estimated that more than 9,500 jobs will be created in the long term as their contracts and technologies develop. These direct PIER-supported jobs will create further jobs as employers purchase the goods and services they require while employees spend their earnings. In total, the creation of nearly 27,700 direct, indirect, and induced jobs is projected in the long term as a result of these projects. These 9,500 jobs are in addition to the 1,060 jobs that Energy Commission RD&D contractors identified or estimated in 2011 and 25 additional jobs identified in early 2013.[53]

Applying the results of such research can lead to creating and growing new lines of business, which eventually provide private sector output and jobs. PIER research also creates jobs by focusing on research that advances renewable energy deployment, renewable energy integration into the marketplace, and the replacement of fossil fuel generation.

Estimates developed by the California Clean Energy Future suggest that replacing natural gas energy generation with renewable generation will increase employment by 2.5 to 30 times,

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51 Estimates regarding job creation produced by economic staff using contract data about job hours and funding.

52 A. B. Jaffe, R. Henderson, and M. Trajtenberg, "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations" Quarterly Journal of Economics, Vol. CViii, (August 1993), issue 3, p. 577

53 Staff estimated indirect and induced jobs using the IMPLAN® model, a widely recognized economic impact assessment software program.

depending on the type of renewable generation.[54] Similarly, replacing fossil fuel energy generation with energy efficiency measures stands to increase the number of jobs nine times.[55]

Human Power and Energy RD&D: Building the Energy Workforce

The Energy Commission has also made strategic investments to address another resource restraint that faces California's energy future: human resources. Building a smart grid to support the state's energy goals will require a qualified workforce. Energy-related industries that rely on employees with a power-engineering education will experience a 40 percent to 50 percent workforce retirement over the next 10 years, and they will need about 40,000 workers for a rapidly evolving workforce. As a result, there are questions about the numbers and types of workers needed, when the workers will be needed, and which job functions they will serve.

To address this resource constraint, the Energy Commission in 2012 began a research effort, leveraging federal funding and its partnerships with major stakeholders, to develop a statewide smart grid workforce development strategic plan. To develop this plan, which will connect degree and certification programs with future energy market needs, the California Smart Grid Workforce Development Network is engaging electric utilities, California State University campuses, California community colleges, labor unions, and smart grid manufacturers in workforce training in advanced power-systems technologies. The network will identify smart grid technologies that will require additional workforce training and support and develop a nationally replicable model for smart grid workforce development. Begun in early 2012, initial project results have identified the need to train 897 incumbent engineers, 521 new-hire engineers, and 1,306 craft and technical workers over the next five years. The project is also developing a smart grid workforce clearinghouse database to help individuals quickly find resources for training or retraining in smart grid-related careers. These planning efforts will continue, and are expected to yield a comprehensive set of tools to help prepare California's workers for the energy economy envisioned in the state's policies.

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54 California's Clean Energy Future. "Preliminary Estimates of Job Creation." http://www.cacleanenergyfuture.org/documents/PreliminaryEstimatesofJobCreation.pdf. Last updated 01/10/2012.

55 Wei, Max, Shana Patadia, and Daniel M. Kammen. 2010. "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy* 38, No. 2 (February): 919-931. doi:10.1016/j.enpol.2009.10.044. http://rael.berkeley.edu/sites/default/files/old-site-files/CopenhagenClimateConcill-GreenJobs-TLS-04.pdf.

CHAPTER 3:
Conclusion

The rational pursuit of creativity and innovation in California's energy landscape has yielded and will continue to provide enormous returns on the investments made. The PIER program has proven its ability to leverage its own investment funds to bring in private and federal dollars and create jobs while helping California build towards its planned energy future. The innovations funded by PIER save California electricity ratepayers millions of dollars every year, through improved system reliability, higher energy efficiency standards and codes, and the use of PIER-developed technologies and tools. Californians have benefited from products brought to the marketplace to reduce energy demand and costs, enhance generation performance, increase comfort and public safety, reduce environmental waste streams, and promote clean air. The projects highlighted in this report, as well as many others, have directly addressed barriers facing policy goals, sometimes even transforming and advancing the policies themselves as in the case of PIER energy efficiency research.

As a significant influence on the world's economic and energy future, California has taken the leadership role of supporting aggressive policy goals and funding innovative energy projects that result in emerging technologies, standards, and strategies. The Energy Commission has invested $839 million for energy RD&D projects and leveraged its investments to attract $1.35 billion in match funding, reaping benefits that far outweigh the costs. Nobel laureate Robert Solow estimated that more than 90 percent of economic growth comes from investments in innovation. The private rate of return on RD&D is around 20 to 30 percent, while the social rate of return is around 66 percent.[56]

Over the last 15 years, the PIER Program responded to evolving policy goals and market needs. The program initially focused on research involving individual components and progressed to emphasize integration of multiple energy technologies to maximize synergies and benefits. The program also enhanced its capabilities and processes in regards to collection and reporting of benefits data.

PIER has been one of the premier energy research programs in the country since 1996 and one of only several official state programs of its kind in the nation. PIER research transformed the state's energy policy landscape, providing clear and quantifiable results that policy makers and innovators have used to plan for the future. Although the PIER Electricity Research Program is not authorized to fund new future projects, its investments laid a foundation for continued progress toward California's clean energy future. The complexities and challenges of transforming the energy system that powers California are enormous; they must continue to be matched by capable, strategic, and comprehensive investment in innovation.

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56 Nemet, Gregory F. "Policy and Innovation in Low-Carbon Energy Technologies." Ph.D. Dissertation, May 2007. https://mywebspace.wisc.edu/nemet/web/Thesis.html.

APPENDIX A:
List of Projects Funded in 2012

This table summarizes new electricity research projects initiated (that is, agreements approved at an Energy Commission Business Meeting during calendar year 2012. The projects listed below were funded primarily with electricity funds. Also included are projects that were previously initiated but had formal amendments to encumber funds for additional projects in 2012. A total of 30 electricity projects were initiated or amended to encumber additional funds in calendar year 2012.

Agreement Number	Entity	Project Title	Total Agreement Amount	Match Amount	Start Date*
500-08-042	Western Cooling Efficiency Center - UC Davis	Western Cooling Efficiency Center Research: a) New Technology for Ground Source Heat Pumps b) Envelope Sealing with Adhesive Mist c) Phase Change Materials for Hydronic Heating Systems d) Opportunities for Gray Water Re-Use	$800,000	$0	8/30/2012
500-08-044	Center for the Built Environment - UC Berkeley	Advanced Building Systems Technology Development: Personal Comfort Systems	$600,000	$0	8/23/2012

Agreement Number	Entity	Project Title	Total Agreement Amount	Match Amount	Start Date*
500-08-053	California Lighting Technology Center - UC Davis	Realizing Energy Efficient Lighting in California: a) Light Emitting Diode Replacement Lamp Testing Program b) Next Generation Adaptive Interior Lighting c) Next Generation Adaptive Exterior Lighting d) Market Transformations and Standards Support e) Expanding Demonstration Efforts in the Industrial/Agriculture Sector	$1,500,000	$715,000	8/29/2012
500-09-027	Pacific Gas and Electric Company	Pacific Gas & Electric Energy Storage Demonstration: Utility-Scale Battery Energy Storage Demonstration	$500,000	$0	8/30/2012
500-10-052	Lawrence Berkeley National Laboratory	Buildings Energy Efficiency Research Projects: a) Graphical User Interface for Energy Plus b) Energy IQ Action-Oriented Benchmarking c) Improving Residential Programmable Thermostats d) More Efficient Residential Heating/Cooling by Airflow Instrument Standards e) Rating Method for Roof Aggregate	$1,550,000	$0	8/23/2012
500-11-011	University Enterprises, Inc. (on behalf of California State University, Sacramento)	Recovery Act - California Smart Grid Workforce Development Network	$83,355	$749,992	3/23/2012

Agreement Number	Entity	Project Title	Total Agreement Amount	Match Amount	Start Date*
500-11-012	The Regents of the University of California on behalf of the Los Angeles Campus	California Center for Sustainable Communities at UCLA	$1,900,000	$0	4/4/2012
500-11-013	The Regents of the University of California on behalf of the Los Angeles Campus	Implementation of Demand Response in a University Campus	$499,999	$0	5/21/2012
500-11-018	Pacific Gas and Electric Company	Advanced Control Technologies for Distribution Grid Voltage and Stability with Electric Vehicles and Distributed Renewable Generation	$1,535,725	$0	10/16/2012
500-11-019	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Distribution System Field Study with California Utilities to Assess Capacity for Renewables and Electric Vehicles	$1,167,380	$0	8/8/2012
500-11-020	The Regents of the University of California, Davis	Renewable Energy Resource, Technology and Economic Assessments	$2,000,000	$0	7/27/2012
500-11-021	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Underground Electric Cable Diagnostics: Miniaturize, Field Test, and Commercialize State of the Art Sensors	$1,200,000	$0	8/10/2012

Agreement Number	Entity	Project Title	Total Agreement Amount	Match Amount	Start Date*
500-11-026	UC Merced	Impact of Plasma-assisted Biomass Gasification and Power Generation on Air Quality	$258,383	$50,000	8/10/2012
500-11-028	Advanced Power and Energy Program - UC Irvine	Economically and Environmentally Viable Strategies for Conversion of Bioresources to Power	$397,236	$0	10/15/2012
500-11-030	CSU Fullerton	Air Quality Issues Related to Using Biogas from Anaerobic Digestion of Food Waste	$164,201	$0	8/8/2012
500-11-033	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Exploratory Studies of Potential Environmental Issues with Alternative Energy Futures for California	$1,193,197	$0	8/10/2012
PIR-11-005	Sacramento Municipal Utility District	SMUD Community Renewable Energy Deployment	$500,000	$10,136,385	9/26/2012
PIR-11-006	Palo Alto Research Center, Incorporated	Novel Hydrodynamic Separation Technology for Wastewater Treatment	$1,001,899	$380,817	8/14/2012
PIR-11-007	AutoGrid Systems, Inc.	Low-Cost, Scalable, Fast Demand Response for Municipal Wastewater and Recycling Facilities	$1,199,544	$603,100	7/9/2012
PIR-11-010	Berkeley Energy Sciences Corporation	Peak Shaving with Flywheel Energy Storage Device	$1,800,000	$800,000	6/15/2012
PIR-11-011	Great Circle Industries, Inc.	Demonstration of i50 Decentralized Wastewater Treatment/Water Recycling	$750,000	$250,000	7/2/2012
PIR-11-012	Randel Wildlife Consulting, Inc	Effect of Utility-Scale Solar Development and Operation on Desert Kit Foxes	$606,257	$29,710	7/27/2012

Agreement Number	Entity	Project Title	Total Agreement Amount	Match Amount	Start Date*
PIR-11-013	Redlands Institute, University of Redlands	Improving Environmental Decision Support for Proposed Solar Energy Projects Relative to Mojave Desert Tortoise	$563,776	$62,970	6/15/2012
PIR-11-015	Modesto Irrigation District	SGIG Distribution Infrastructure Substation Upgrades	$149,315	$2,837,025	7/9/2012
PIR-11-018	Kennedy/Jenks Consultants, Inc.	Primary Effluent Filtration as an Intermediary Wastewater Treatment Step	$1,418,800	$568,800	7/3/2012
PIR-11-019	Oakbio, Inc.	Carbon Dioxide Capture and Conversion to Chemical Products	$474,843	$176,996	7/2/2012
PIR-11-020	Black & Veatch	Full-Scale Demonstration of an Innovative Electrodialysis Technology for Zero Liquid Discharge Desalination	$799,860	$249,000	10/25/2012
PIR-11-021	Altex Technologies Corporation	Demonstration of full scale Biomass Blending and Densification System (BBADS)	$1,390,941	$481,391	6/25/2012
PIR-11-022	Shawn Smallwood, sole proprietor	Test of Avian Collision Risk of a Closed Bladed Wind Turbine	$716,596	$174,498	5/31/2012
PIR-11-025	Kiverdi, Inc	CO2 to Oil Production Using Kiverdi's Novel Microbial System	$747,126	$587,027	6/20/2012

*Start Date is the date the agreement was signed and executed.

ACRONYMS

AB Assembly Bill
ARB California Air Resources Board
ARRA American Recovery and Reinvestment Act
AutoDR automated demand response
AWT airborne wind turbine
BBEST boiler burner energy system technology
BLM Bureau of Land Management
California ISO California Independent System Operator
CCS carbon capture and storage
CHP combined heat and power
CO_2 carbon dioxide
CPU central processing unit
CPUC California Public Utilities Commission
DFG California Department of Fish and Game
DG distributed generation
DOE United States Department of Energy
DRECP Desert Renewable Energy Conservation Plan
EISG Energy Innovations Small Grant
EPIC Electric Program Investment Charge
FDD fault detection and diagnostics
GHG greenhouse gas
GWh gigawatt hour(s)
HEED Home Energy Efficient Design
HVAC heating, ventilation, and air conditioning
IAW industrial, agriculture, and water
IEPR Integrated Energy Policy Report
IP intellectual property
IT information technology
kW kilowatt(s)
kWh kilowatt hour(s)
LED light-emitting diode
MTG microturbine generator
MW megawatt(s)
MWh megawatt hour(s)
NOx nitrogen oxide
OIR Order Instituting Rulemaking
PAGs Program Advisory Groups
PEV plug-in electric vehicle
PGC Public Goods Charge
PHEV plug-in hybrid electric vehicle
PIER Public Interest Energy Research
PV photovoltaic
R&D research and development
RD&D research, development, and demonstration
RESCO Renewable Energy Secure Community
RPS Renewables Portfolio Standard
SB Senate Bill
SDG&E San Diego Gas & Electric
UCSD University of California, San Diego
WESTCARB West Coast Regional Carbon Sequestration Partnership